Lubrication ENGINEERING

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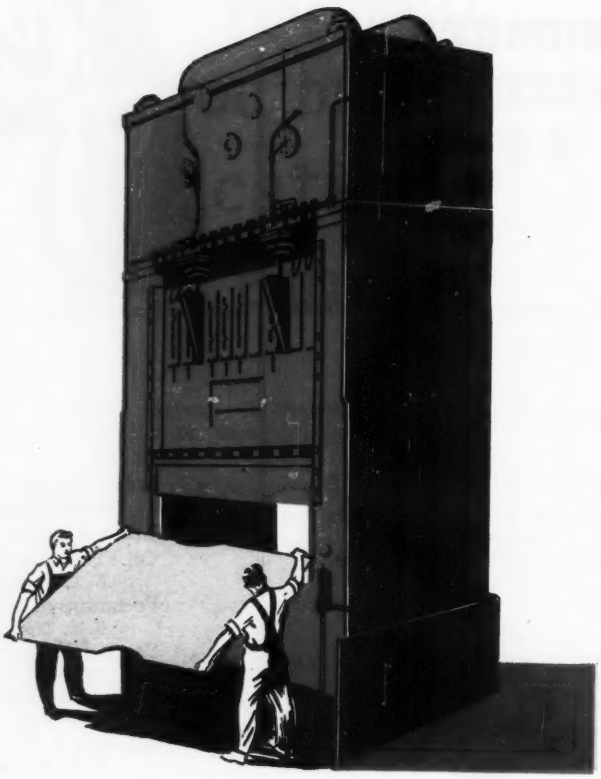


FARVAL—*Studies in Centralized Lubrication No. 85*

FARVAL
CENTRALIZED SYSTEMS OF LUBRICATION

Editorial -- Industrial Research Trends*

By HAROLD VAGTBORG
President, Midwest Research Institute, Kansas City, Missouri

Introduction

There are very definite trends in industrial research in general and in research as it relates to lubrication. We will first discuss those that relate to industrial research.

Michael Pupin once said that "Science is simple! Science is Man listening to the language of Nature and trying to understand it." It is through this process that the incentives for research have been ever on the increase. A better knowledge of nature and her laws has produced more and better jobs, better products, and greater profits. In this connection it is a matter of record that the research developments produced in our laboratories since just prior to the year 1900 have created new industries which today employ fifteen million people.

These incentives can be related to the growth of our research laboratories which numbered only a handful from 1900 almost through World War I. Today there are approximately 2,500 laboratories that employ 70,000 workers and expend approximately $350,000,000 per year. This covers normal industrial aspects and does not include the tremendous expansion of research brought about by World War II when the total research expenditures in one year reached almost $800,000,000.

The National Association of Manufacturers has reported that in 1941 a survey indicated that the 1,008 manufacturers responding averaged research expenditures of 1.1% of gross sales. We know that there are many chemical companies that expend in the neighborhood of 5% of gross sales. The fact is that this development and research interest in American industry has been brought about because research has paid off. There is a definite trend toward research investments developing toward an annual expenditure of a billion dollars per year. We need not assume this figure is fantastic for it represents in the neighborhood of ¾ of 1% of gross national income. It was recently reported from a good source that Russia is already expending 1% of gross national income on research.

* *Presented before First Spring Meeting, The American Society of Lubrication Engineers, Chicago, Illinois, April 5, 1946.*

Research as a Vital Part of Industry

A second significant trend that is becoming more obvious is the better realization that new industries can be created in the face of the keen competition of the "older line industries" if the new ones are willing to consider research laboratories as their greatest asset.

In this regard Edwin H. Land, president and founder of the Polaroid Corporation said, "I believe that the small company of the future will be as much a research organization as it is a manufacturing company, and that this new kind of company is the frontier of our next generation.

"The business of the future will be a scientific, social, and economic unit. It will be vigorously creative in pure science, where its contributions will compare with those of universities. Indeed, it will be expected that the career of the pure scientist will be as much in the corporation laboratory as in the university."

This trend may be summarized as the better realization that "today's science is tomorrow's engineering, and the next day's industry."

The third trend, a statistical one, is the increase in the number of research laboratories. Many companies that have never heretofore engaged in research are developing research departments. Numerous new laboratories are contemplated, not as small areas in the corner of a factory building, but as separate buildings around which have been created the best environment for the successful prosecution of the development of new products and processes through research. However, even if our laboratories increase tenfold there will be but 25,000 laboratories in the United States, leaving approximately 150,000 manufacturing organizations, particularly smaller ones, which will still need the facilities in order to stay in business.

Research is becoming more than ever the common denominator in American industry and the smaller organizations will only be able to secure this service through the "pooling" of their research investments and facilities. This pooling of interests has brought about the development of many research institutions. In the past years we had only a few institutions of this type such as Mellon Institute of Industrial Research and Battelle Memorial Institute, but recent years have seen the development of the Armour Research Foundation of Illinois Institute of Technology, Midwest Research Institute, and Southern Research Institute, as well as many research institutes associated with our colleges and universities.

At the present time there are, in process of development, two research organizations on the West Coast, one to serve primarily California and the other to serve the Pacific Northwest.

A significant trend in industrial research is possibly best keynoted by the expression, "a closed door keeps out more than it keeps in." World War II has shown industry that there are many advantages in pooling our knowledge on those problems of a basic nature. The production of synthetic rubber in great quantities during the war was brought about by a pooling of knowledge and there is a strong trend toward the maintenance of closer association among our research groups on "common denominator" problems. Such procedure still gives the individual research departments the opportunity for competition which is built around the development of better techniques and lower production costs rather than a better knowledge of the basic laws of nature. The ultimate benefactor, the general public, will gain significantly as a result of this trend. The trend is well expressed through such organizations as the Institute of Paper Chemistry, Institute of Gas Technology, and the Textile Research Institute. It also takes the form of a Cotton Council, the Sugar Foundation, the Nutrition Foundation, and the Iodine Foundation.

Another expression of this type of cooperation is the establishment of neutral laboratories available to an entire industry, a good example of which is the Diesel lubricant laboratory at the Armour Research Foundation.

A fifth trend in industrial research is the increasing use of university and college facilities. As the colleges are learning to understand the industrial tempo better, their facilities are being used more extensively. Many colleges and universities have streamlined their services to industry by

setting up groups within the faculty which are primarily responsible for industrial problems.

A further trend of note is that research efficiencies are being increased. In the first place there are new tools of science that are becoming universally used. These are many, but a few that have become common are electron microscopy, X-ray diffraction, and spectroscopy. Increased efficiency in research is one of the soundest answers to the problem of the shortage of scientists. Not long ago there were too many Ph. D. plumbers and carpenters in our research groups. These scientists too often were expected to acquire equipment, assemble it, make all of the modifications and operate it, in addition to their basic functions of thinking out the solutions to problems. Such procedures drastically reduced efficiencies and there are too many cases on record where 11 months of the year were spent by the scientist doing those things that technicians and laborers could have accomplished. In the modern laboratory research is facilitated with service departments and, moreover, in most of them can be found represented many of the building trade vocations to speed up the work of the scientists.

Red tape in operations is being reduced and the research environment is being improved. A better understanding exists between the members of the staff and the management. This understanding is developing largely through a better appreciation of the value of science in industry.

A seventh significant trend in industrial research in general relates to the up-grading of research management's position in a corporation. Research is being considered as less of a "frill" than it has in the past. It is now thought of as the "heart" pumping new lifeblood into a company. Research has taken its place in the annual report. The research director is not locked up in a dingy laboratory in the corner of a plant, reporting as infrequently as necessary to the sales, advertising or production department. Numerous new vice presidencies are being created to take care of research and development. These men may well be termed the "Vice Presidents in Charge of the Future," and they sit in on councils of management and decide on major company policies.

A further trend is the relationship of banking interests to research. Bankers are beginning to seek counsel about research and its possible effect on corporation financing. Many commercial loans are determined more by a research alertness on the part of management and less by the balance sheet. It is also interesting to note that to a lesser extent bankers and lawyers are becoming presidents of manufacturing corporations and to a greater extent technologists are taking their place.

A ninth trend may be stated as the trend toward more objectiveness in a product and less subjectiveness. In other words, the often heard statement of years past, "I am not interested in that part of our product produced by others because as company policy we expect our supplier to do research on that phase" is becoming a statement of the past. The manufacturer realizes more than ever that component parts or functions of his product that are made by others cannot be disregarded but that competition requires that the total overall product is his final responsibility.

Fountain pen manufacturers have found that they cannot be satisfied with producing a good fountain pen but that competition requires that they also produce a good ink to go with the fountain pen. The machine tool industry is very much concerned with lubrication even though it may be provided by others. Let this be a word of caution to our lubrication manufacturers because if they do not keep pace with the development of machinery they will find that machinery manufacturers will be producing the lubricant tailored to fit their needs.

A final trend that we might here consider, although there are many others, is the trend of producing a product in a technology package. Sales engineers who understand the technology and application of the product are rapidly taking the place of high pressure artists. Technology has become an important sales factor and both the seller and buyer have technologists on their staffs who can evaluate a product from the point of view of the seller and buyer.

Trends in Lubrication Technology

We have discussed some of the general trends in industrial research. There are definite trends in lubrication technology.

Machine tools are becoming more complex, more costly, and more automatic largely because of the fact that with higher labor costs a higher standard of living can only be maintained by greater machine efficiency. This results in higher speeds and more attention to the problem of lubrication. It means closer tolerances and better and longer lasting lubricants, for we can less than ever afford to have machinery out of commission.

Although significant progress is being made in lubrication technology, there are still many of even the basic problems about which too little is understood. Who can answer the following questions to the satisfaction of all? What is a lubricant? What does it do? How does it act? What is friction? What is the motion of the lubricant? What about the surface involved?

We do know that "Joe" with the universal oil in an oil can is not going to do the job any more. We are only going to be able to answer the basic questions of lubrication by studying the fundamentals involved. We must get away from any notion that a quick and permanent answer is obtained by a cut and try procedure. Mathematics is destined to enter much more into the solutions of these problems than the cut and try concoction. X-ray diffraction to study molecular arrangement of lubricants, the electron microscope to study surfaces, and the mathematics of viscous fluids will become more and more the tools of lubricating engineers in the future.

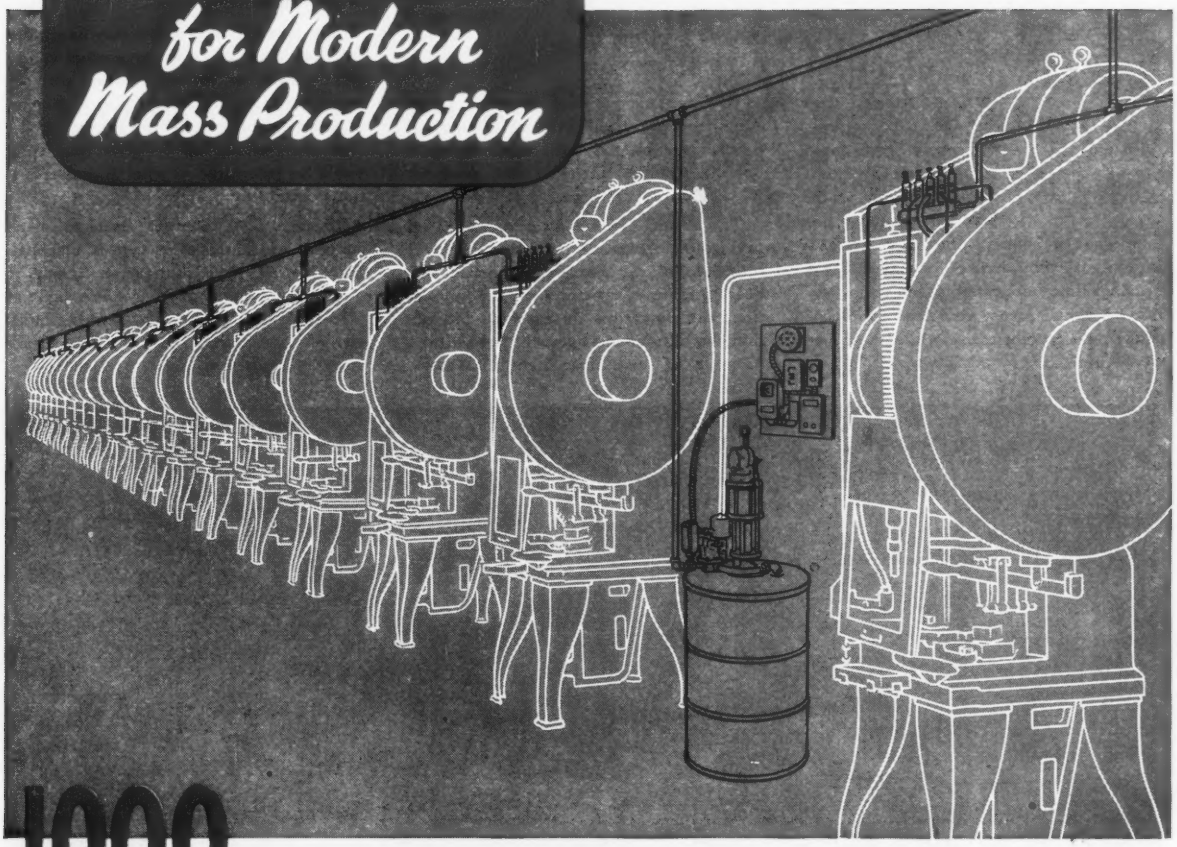
By a fundamental scientific approach to the problems of lubrication, we will change the statement so often heard to the effect that "what we know about lubricants is about as little as we know about any other subject."

Conclusion

No company is large enough to assume the responsibility of developing the basic science of lubrication. This can only be done through group action and in this regard the American Society of Lubrication Engineers has a golden opportunity to become a catalyst. Much can be accomplished through committees representing research groups from all walks of the industry, and much will come from group research on basic problems.

When the basic knowledge in lubrication technology is determined, the pattern is set. Then the job of the individual lubricant manufacturer will be to better tailor his product to the needs of his customers.

Mass Lubrication for Modern Mass Production



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The above schematic drawing illustrates a Lincoln Centro-Matic System installed in large Mid-Western industrial plant. It is typical of how these outstanding systems are being applied to lubricate industrial machinery. The installation is simple—all that is required is a Centro-Matic Injector connected to each bearing, singly or in manifold, and a single lubricant supply line from a centrally located lubricant pump, which can be time clock or push button controlled, power operated or manually operated. The flexibility of Lincoln Centro-Matic Systems makes it possible to install them on a single machine or a battery of machines and only one lubricant pump is required.

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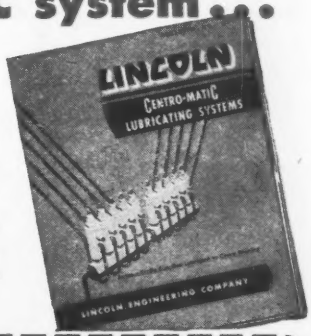

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How an Inexpensive System SAVES $8,000 A YEAR

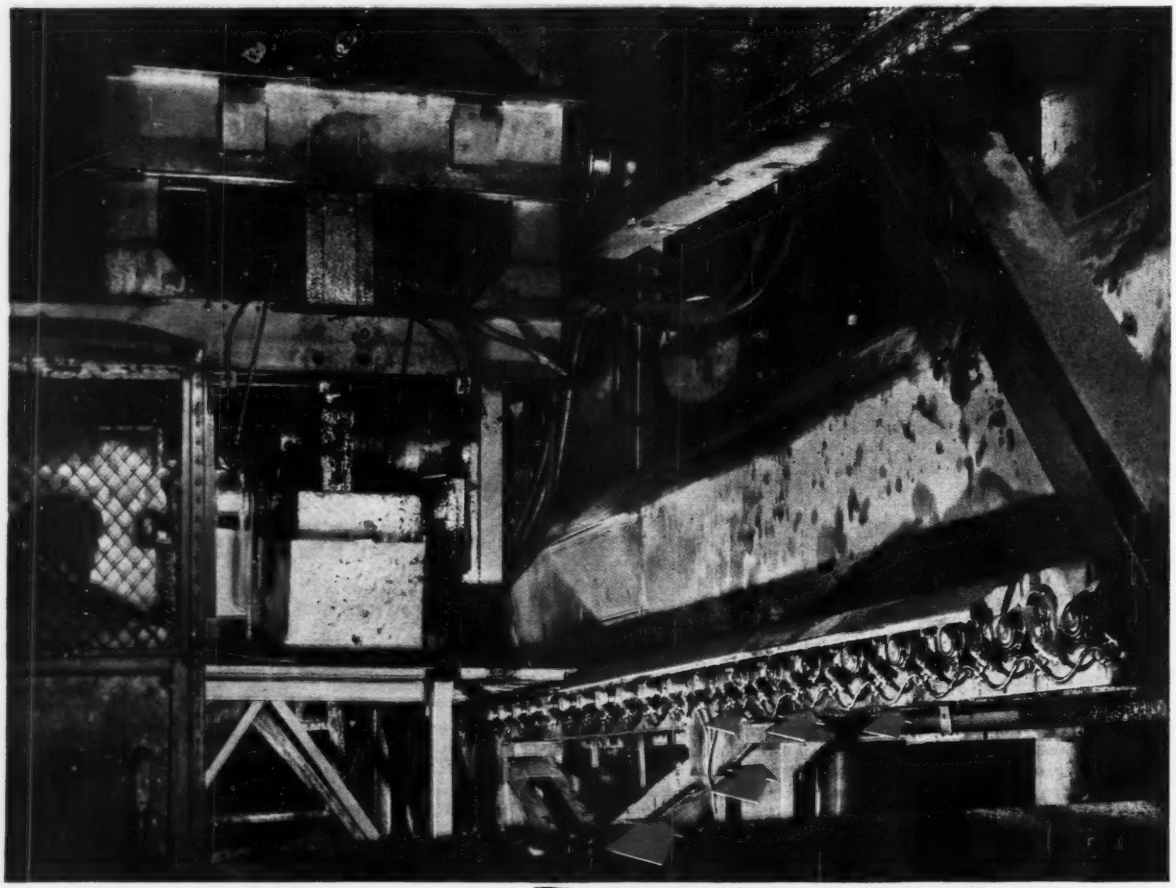
GLOBE Steel Tubes Co., Milwaukee, Wisconsin, considered to be the most modern manufacturer of seamless steel tubing, has hundreds of heavy machines literally loaded with thousands of bearings. These bearings function at high speed under terrific heat, and many were inaccessible or could not be lubricated while machines were running.

To meet this problem, Globe installed Alemite Centralized Systems. Today, all machines equipped with these Systems operate 3 shifts and *never* shut down for lubrication!

The result — Globe estimates over-all savings in lubrication costs this year will total $8,000 . . . through elimination of bearing failures, overtime pay for lubrication, and downtime on machine production. No wonder management has set up a program of installing Alemite Systems *exclusively* on present machines as well as on new machines to come.

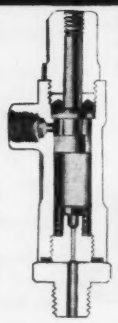
Your lubrication problem may be similar to Globe's. Or you may have other conditions — such as excessive dust, dirt, or moisture, operational hazards, human error, need for cleanliness, bearings overlooked — that are running up costs. In any case, you'll be interested in what Alemite Systems can do for you.

There are 4 Alemite Systems, each adaptable to almost every type of machine. Have an Alemite Lubrication Specialist demonstrate one or all 4 Systems right at your desk with transparent working models. Write Alemite, 1835 Diversey Parkway, Chicago 14, Illinois.



The huge rotary hearth furnace, and the hot conveyor at right foreground, are lubricated with Alemite LubroMeter Centralized Systems. Hundreds of machines in the Globe plant are also LubroMeter equipped.

Here's What Makes an Alemite Centralized Lubrication System "Tick"



This is a cutaway view of an Alemite LubroMeter feeder valve. It may be mounted directly in the bearing and handles grease or oil. To lubricate a machine, *even while it is in operation,* lubricant is introduced at a central point and forced through metal "arteries" to the feeder valves. These valves discharge a measured amount of lubricant to every bearing in the system. An indicator on each valve signals when the bearing is correctly lubricated. The over-all savings can enable you to amortize an Alemite Centralized System in as little as 3 months.

STEWART WARNER

ALEMITE

Centralized Lubrication Systems

Oil Filtration and Its Effect on Engine Wear*

By NORMAN C. PENFOLD AND DONALD S. GRAY

Armour Research Foundation

* * * * * * * * * * * * *

A series of full scale, long term engine tests were made to study the effect of oil filtration on engine wear. Wear rate trends determined by mechanical measurement and by chemical analysis were used to evaluate engine wear characteristics when the lubricating oil filtration was partial flow and full flow, and when no oil filter was used.

The value of the oil filter in reducing engine wear, and a comparison of the relative value of the partial and full flow systems in reducing engine wear under controlled laboratory test conditions, as well as an investigation of the mechanism of filter action in removing products of cylinder wear from the lubricating oil are the subjects of this paper.

* * * * * * * * * * * * *

Introduction

ENGINE wear, a term arbitrarily defined for the purposes of this paper as the removal of metal from piston rings and cylinder walls, can be increased or decreased in engines operated under controlled test conditions according to the test procedure used. Other investigators have demonstrated that engine wear rates are influenced by speed and load, start and stop operation, run-in procedure, cylinder and piston ring material and surface finish, abrasive particles introduced into the induction system, coolant and lubricating oil temperatures, the type of fuel, the air-fuel ratio, and by fuel and lubricant contamination.

This investigation was concerned with determining whether engine wear rates could be effected by filtering the lubricating oil in a test engine with all known variables held constant. If it was found that lubricating oil filtration did effect engine wear, it was planned to investigate the phenomenon of how this wear reduction was accomplished.

The Scope of the Investigation

A search of the available literature indicated that, on the basis of carefully controlled laboratory tests, little previous work had been done to determine if engine wear rates could be effected by filtering the lubricating oil. It is probable that investigations of similar nature have been made, however, and the results not published.

Since partial flow, or by-pass filtration is the most common system of lubricating oil filtration, the first part of the investigation consisted of a determination of the wear rate that could be expected in a commercial type engine operated for extended periods with partial flow lubricating oil filtration.

When this partial flow wear rate was established, it was planned to determine the wear rate for this engine operated under the same test conditions, first, with no oil filter, and second, with a full flow filtration system. These wear rates would be based on engine wear as previously defined, as well as on the amount of metal retained in the filters, on the quantity of metal in the drain oil and washings, and on the increase in iron content of the lubricating oil.

Test Equipment

A four-cylinder Caterpillar Diesel engine, Model D4400, as shown in Fig. 1, having a 4-¼ inch bore and

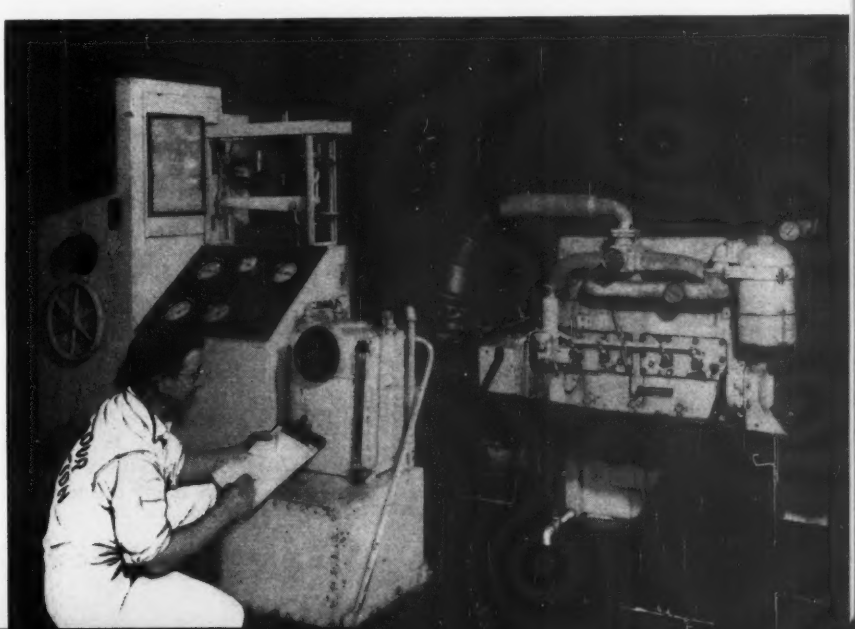


Figure 1 →

* *Presented at the S.A.E. National Fuels and Lubricants Meeting, Tulsa, Oklahoma, November 8, 1946. Published by permission.*

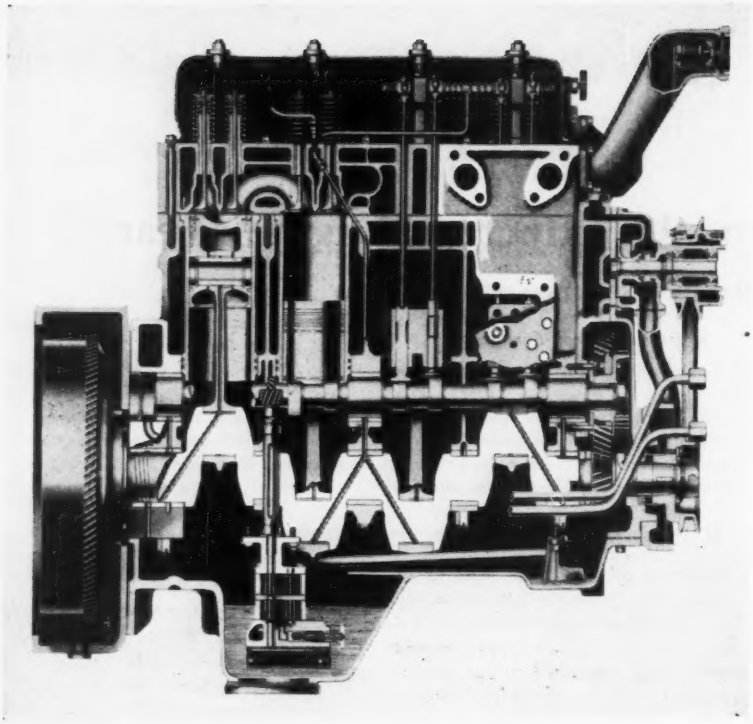


Figure 1A

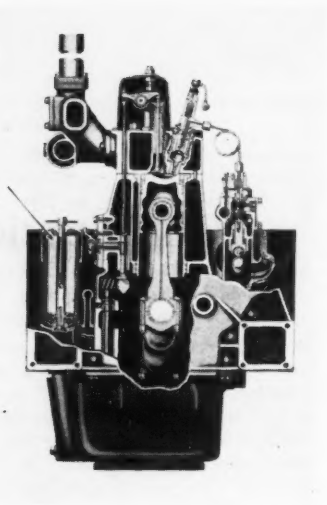


Figure 1B

a 5½ inch stroke, was used in all tests. This engine was installed on Armour Research Foundation test stand No. 10, and coupled to a cradled induction-generator dynamometer.

The D4400 was selected for this test series because of its demonstrated ruggedness and reliability, and because of the large amount of experience the investigators had gained in using the D4400 in oil test programs.

For the tests in which the partial flow system of oil filtration was used, a standard absorbent type filter, having a by-pass ratio given as approximately 6 to 1, was installed.

For the full flow filtration tests, the pressure activated relief valve in the engine oil line was blocked, and a special filter housing with six absorbent filters was installed. Figure 1 shows the D4400 test engine with the full flow filter installed. Figure 1-A is a cutaway side view of the D4400 engine, and Fig. 1-B is a cutaway front view showing the partial flow filter installation.

For tests in which the lubricating oil was not filtered, the only change in the D4400 engine was the removal of the absorbent filter. Figure 2 is the filter with a cutaway section to show the construction.

Special equipment developed for these tests included a cylinder wear measuring device designed to eliminate the influence of cylinder liner distortion on the results of cylinder wear measurement obtained by the usual methods of diametrial measurement. See Appendix A.

An SAE 30 grade compounded lubricant, meeting 2-104B specifications, was used for all tests. The lubricant used was selected because of the large amount of engine test data obtained in previous test work on it.

Test Procedure

Each engine test comprised 360 hours of engine operation at 1400 rpm with a 37 bhp load. During this period the engine jacket temperature was maintained at 160F, and the lubricating oil temperature at 180F. The intake air temperature was not controlled but variations were slight and the oil bath-type air cleaner was cleaned and charged with fresh oil at the start of each test and after each 120 hours of engine operation.

The lube oil flow usually varies from 225 to 240 gallons per hour for this engine, and the flow through the partial flow filter, with a by-pass ratio of 6 to 1, would be from 37.5 to 40 gallons per hour. The oil filters were changed after each 60 hours of test operation. A six-ounce sample of the lubricating oil was withdrawn from the engine oil gallery after each 30 hours of test operation. For the tests with no oil filter, the test procedure was the same as for the partial flow and full flow filtration tests, with the exception of the 60-hour interval shut-downs.

At the conclusion of each test, the cylinder head was removed and washed with a solvent composed of 40 percent ethyl acetate, 30 percent denatured alcohol, 5 percent butyl alcohol and 25 percent orthodichlorbenzene. The interior of the engine was washed with this solvent after the pistons and cylinder liners had been removed. This washing procedure was instituted to insure that all of the metal removed during a test would be cleaned out of the engine so as not to effect the results of the succeeding tests and to provide accurate metal removal data.

These washings were saved for chemical analysis for iron content, as were the filters, and all oil samples. The piston ring weight loss, change in radial thickness, and gap increase were also determined.

Test Result Evaluation Procedure

Engine wear rates were evaluated from a determination of the weight loss of the piston rings during a test, the ring gap increase, and the dimensional change. Each piston ring was weighed to one milligram, the ring gap measured to 1/1000 in., and the lateral dimensions of the ring measured to 1/10,000 in. at six intervals around the circumference.

TABLE NO. 1—ENGINE OPERATION DATA

	Partial Flow Filtration Test No.				Full Flow Filtration Test No.			No-Filter Test No.		
	1	2	3	4	1	2	3	1	2	3
Engine Jacket Temp. F										
Maximum	162	162	162	162	160	162	160	167	164	164
Minimum	156	160	160	159	160	160	160	154	156	156
Average	159	160	160	160	160	160	160	160	161	160
Oil Sump Temp. F										
Maximum	187	187	182	188	185	184	184	186	185	191
Minimum	170	164	176	160	170	167	174	174	164	176
Average	179	181	179	185	180	179	179	180	179.5	185
Exhaust Temp. F										
Maximum	875	820	800	855	820	795	890	810	840	770
Minimum	760	785	760	800	765	755	835	725	720	690
Average	817	800	770	820	775	775	875	774	772	722
Blow-by, cfh										
Maximum	25	19.8	17.8	25.6	17.4	16.6	27.5	18.6	18.4	23.3
Minimum	16	13.8	12.1	18.4	13.8	8.4	22.8	13.1	10.2	16.2
Average	20.5	17.0	15.5	22.0	15.5	13.6	25.0	16.5	16.34	18.3
Oil Economy, hrs./gal.										
0-120 hrs.	57	...	64.6	41.7	27.6	38	29.7	82.7	66.3	72.6
120-240 hrs.	113	138	149	70.8	49.6	31	32.1	143	96.6	71.5
240-360 hrs.	148	149	207	85.7	40.7	35	56.4	106	84	83

Bearing wear, wrist pin wear, and wear of other engine parts commonly measured in connection with wear studies were not determined for this test series. It was felt that the value of these data in confirming trends shown by upper cylinder wear would be more than nullified by the labor required to interpret this wear in terms of clearness, particle sizes, etc.

The engine wear rates were also evaluated from the results of analysis for increase in iron content of drain oil and washings and of the oil filters, in order that the wear rate as determined by chemical analysis could be compared with the wear rates determined by mechanical measurement. The oil samples taken at the 30-hour periods, and the drain oil and washings, were analyzed for their iron content by the Colormetric or Trace Analysis Method, while the oil filters were ashed and analyzed for iron content by the Potassium Dichromate Method.

Analysis of Oil from Air Cleaner

To help determine the effectiveness of the engine air cleaner, oil from an air cleaner on the D4400 engine was removed after 120 hours of test operation, and analyzed. The oil was filtered, and the filter paper and the residue were dried and ashed. A clean filter paper was also ashed. The residue was found to be composed of fine particles, and the iron content was low. The weight of dried residue was 2.7250 g., while the weight of ash from the residue was 1.6244 g.

The chemical composition of the ash was reported as

S_1O_2	39.75%	
R_2O_3	43.55%	(mostly Fe_2O_3)
CaO	6.85%	
MgO	2.60%	
Cr_2O_3	0.75%	
SO_4	5.85%	

HCl solubles were 49.6% and insolubles, 50.4%.

The results of an X-ray diffraction analysis were reported as

Sand	about 50%
Fe_2O_3	about 30%
$CaSO_4$	about 10%
Unidentified	about 10%

The presence of $CaSO_4$, SO_2 and Fe_2O_3 was confirmed by refractive index measurements, as well as other crystallographic properties characteristic of those phases. Other crystalline phases, probably silicates, were also observed.

The best overall analysis of the material removed by the oil in the air cleaner is given as:

Sand	37.4%
Fe_2O_3	43.6%
$CaSO_4$	10.0%
Silicates	5.0%
MgO	2.6%
Cr_2O_3	0.7%

Discussion

The engine operating data tabulated in Table No. 1 show that the important engine operating variables, jacket and lubricating oil temperatures, were held under very close control. The speed and load were constant for all tests, and the comparison of exhaust temperatures and crankcase blow-by for all tests also shows that engine operation and general engine conditions were

Figure 2

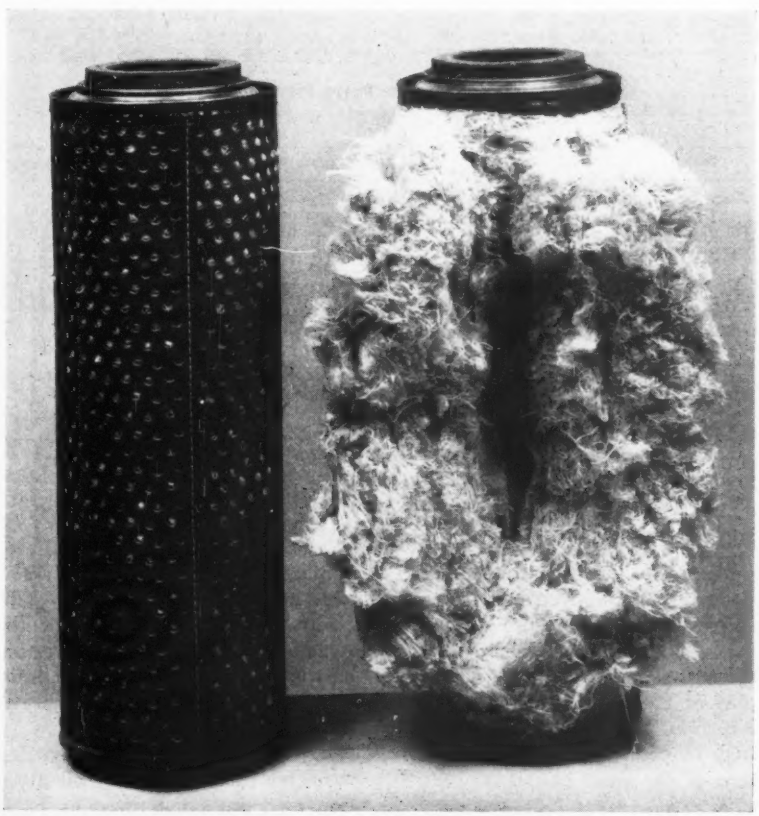


TABLE NO. 2—PARTIAL FLOW FILTRATION TESTS PISTON RING WEAR

	Test No.				
	1	2	3	4	Average
Average Weight Loss, mg.					
1st Compression Ring	326	329	299	334	322
2nd Compression Ring	83	66	50	64	65.8
3rd Compression Ring	38	25	24	27.5	28.6
1st Oil Ring	26	19	18	24.5	21.9
2nd Oil Ring	11	6	8	21	11.5
Average Gap Increase, 1/1000 in.					
1st Compression Ring	...	...	10	12	11
2nd Compression Ring	...	...	6	4.5	5.3
3rd Compression Ring	...	...	3	0	1.5
1st Oil Ring	...	...	3	2.2	2.6
2nd Oil Ring	...	...	1.5	2.5	2.0
Average Dimensional Change 1/10,000 in.					
1st Compression Ring	11.9	14.5	11.0	16.8	13.6
2nd Compression Ring	4.5	2.2	2.2	2.6	2.87
3rd Compression Ring	4.3	2.1	1.8	1.5	2.47

TABLE NO. 3—FULL FLOW FILTRATION TESTS PISTON RING WEAR

	Test No.			
	1	2	3	Average
Average Weight Loss, mg.				
1st Compression Ring	278	261	324	287.7
2nd Compression Ring	45	38	51	44.7
3rd Compression Ring	24	18	20	20.7
1st Oil Ring	14	14	9	12.3
2nd Oil Ring	4	4.5	2	3.5
Average Gap Increase, 1/1000 in.				
1st Compression Ring	7.2	9.4	9.4	8.7
2nd Compression Ring	1	1.2	1.2	1.13
3rd Compression Ring	1	1.1	1.1	1.1
1st Oil Ring	4.5	.5	.5	1.8
2nd Oil Ring	3	.2	.2	1.1
Average Dimensional Change 1/10,000 in.				
1st Compression Ring	9.5	13.5	11.8	11.6
2nd Compression Ring	1.8	2.0	1.3	1.7
3rd Compression Ring	1.1	1	1.1	1

TABLE NO. 4—NO-FILTER TESTS PISTON RING WEAR

	Test No.			
	1	2	3	Average
Average Weight Loss, mg.				
1st Compression Ring	360	372	417	383
2nd Compression Ring	92	86	122	100
3rd Compression Ring	38	40	76.5	51.5
1st Oil Ring	39	37	66	47.4
2nd Oil Ring	28	29.5	49.5	35.6
Average Gap Increase, 1/1000 in.				
1st Compression Ring	13	9.3	13.8	12
2nd Compression Ring	4	5.3	6.5	5.3
3rd Compression Ring	2	3.2	4.3	3.2
1st Oil Ring	2.5	8.5	6.8	5.9
2nd Oil Ring	1	5.5	7.5	4.7
Average Dimensional Change 1/10,000 in.				
1st Compression Ring	11.1	12.4	14.6	12.7
2nd Compression Ring	2.7	3.3	4.8	3.6
3rd Compression Ring	4.5	2.3	3.8	3.5

similar. The lube oil economies can not be compared over the whole test series accurately because of differences in filtration from one test series to another, but the oil economy of Partial Flow Filtration Test No. 1 in Table No. 2, for example, may be compared to the oil economies of the other partial flow filtration tests.

Since all engine operating variables have been maintained sufficiently uniform, the effect of the variation in lubricating oil filtration on the wear rate of the engine may be determined from an analysis of the test results.

The values of average piston ring wear for each method of oil filtration used are summarized in Table No. 5, and illustrated in Fig. 3. These piston ring wear values show that the top compression ring weight losses, while similar for each test of an individual series, tend to differ sharply from one test series to the next. The average top compression ring weight loss in tests in which the oil filtration was partial flow was 322 mg, with a variation within this series of only —7% to +4%; 288 mg for the full flow filtration test series with a variation of —9% to +12%; and 383 mg for the test series with no oil filter, with a variation of —6% to +9%. The top compression ring weight loss was chosen for this comparison because this ring tends to have the highest weight loss, but the other compression rings tend to wear at proportional rates.

The average of the total weight losses for all piston rings of the partial flow test series is 448 mg, for the full flow series 369 mg, and 618 mg for the test series in which no oil filter was used. If the laboratory test engine equipped with a partial flow filter is considered a "standard" engine for evaluation purposes, these data indicate that removing the oil filter will decrease engine life, as measured by cylinder wear rate, by approximately 38 percent for this engine, and that by changing to a full flow system with the same type of filter will increase engine life by approximately 18 percent.

That the full flow filtration system is more effective in reducing engine wear than the partial flow system may be further substantiated by the results tabulated in Table No. 6, and illustrated in Fig. 4. These results show that the iron removed by the oil filters averaged 880 mg more removed in the full flow filters than in the partial flow filters. Data compiled in Table No. 7 show that even when the total iron removed from the engine and recovered in the oil filter is reduced to a "per filter" basis in recognition of the fact that six times as much filter surface was utilized in the full flow filter installations, the full flow system is still more effective. One hundred and ten mg more iron was removed by the filter, per filter used, in the average full flow filtration test as compared to the average partial flow filtration test as shown in Fig. 5.

Chemical analyses were made to determine the increase in iron concentration of the oil samples taken from the engine gallery, and to determine the increase in weight of the iron in the engine drain oil and

TABLE NO. 5—COMPARISON OF AVERAGE PISTON RING WEAR FOR FULL FLOW, PARTIAL FLOW AND NO-FILTER TESTS

	Full Flow Tests	Partial Flow Tests	No-Filter Tests
Average Weight Loss, mg.			
1st Compression Ring	287.7	322	383
2nd Compression Ring	44.7	65.8	100
3rd Compression Ring	20.7	28.6	51.5
1st Oil Ring	12.3	21.9	47.4
2nd Oil Ring	3.5	15.5	35.6
Average Total	368.8	447.8	618
Average Gap Increase, 1/1000 in.			
1st Compression Ring	8.7	11	12
2nd Compression Ring	1.1	5.3	5.3
3rd Compression Ring	1.1	1.5	3.2
1st Oil Ring	1.8	2.6	5.9
2nd Oil Ring	1.1	2	4.7
Average Total	12.4	22.4	31
Average Dimensional Change, 1/10,000 in.			
1st Compression Ring	11.6	13.6	12.7
2nd Compression Ring	1.7	2.9	3.6
3rd Compression Ring	1.1	2.5	3.5

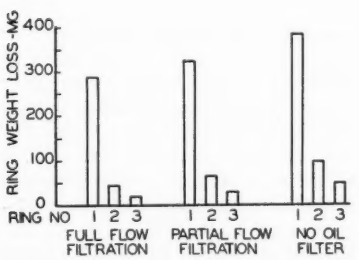


Figure 3. Piston Ring Wear in Average Full and Partial Flow Filtration and No-Filter Tests.

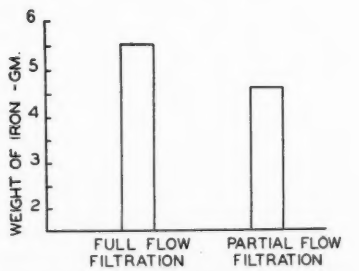


Figure 4. Total Iron Removed by Filters in Average Full and Partial Flow Filtration Tests.

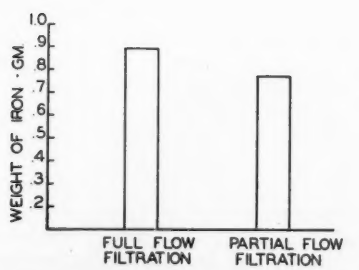


Figure 5. Total Iron Removed per Filter Used in Average Full and Partial Flow Tests.

TABLE NO. 6—TOTAL IRON (FE) REMOVED IN FILTERS

Full Flow	
Test No. 1	5.56 Grams
Test No. 2	5.31 Grams
Test No. 3	5.10 Grams
Average	5.52 Grams
Partial Flow	
Test No. 1	5.96 Grams
Test No. 2	3.99 Grams
Test No. 3	3.78 Grams
Test No. 4	4.82 Grams
Average	4.64 Grams

TABLE NO. 7—AVERAGE TOTAL IRON (FE) REMOVED PER FILTER USED

Full Flow	
Test No. 1	0.93 Grams
Test No. 2	0.89 Grams
Test No. 3	0.85 Grams
Average	0.89 Grams
Partial Flow	
Test No. 1	0.99 Grams
Test No. 2	0.67 Grams
Test No. 3	0.63 Grams
Test No. 4	0.69 Grams
Average	0.77 Grams

TABLE NO. 8—AVERAGE INCREASE OF IRON (FE) CONCENTRATION IN OIL SAMPLES

Full Flow	
Test No. 1	.00087%
Test No. 2	.00067%
Test No. 3	.00087%
Average	.00080%
Partial Flow	
Test No. 1	.00147%
Test No. 2	.00187%
Test No. 3	.00181%
Test No. 4	.00165%
Average	.00171%
No Filter	
Test No. 1	.00978%
Test No. 2	.00805%
Test No. 3	.01340%
Average	.01040%

washings. These analyses are summarized in Tables No. 8 and 9, respectively. If the engine equipped with the partial flow filtration is again chosen as a "standard" for comparison purposes, it will be found that the average oil sample taken from the gallery of the engine without a filter will contain roughly six times as much iron, while the sample from the engine with the full flow filtration will contain approximately one-half as much iron, as illustrated in Fig. 6.

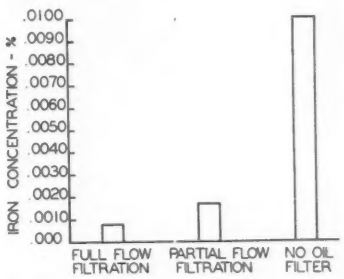


Figure 6. Average Increase of Iron Concentration in Lube Oil Samples.

These values are closely checked by the results of the chemical analyses for the increase in weight of iron in the engine drain oil and washings tabulated in Table No. 9, and illustrated in Fig. 7. The average weight of iron found in the engine drain oil and washings at the

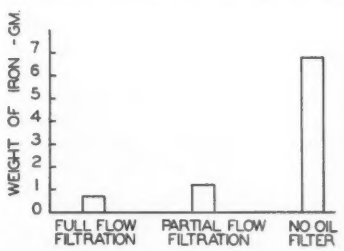


Figure 7. Average Increase in Weight of Iron in Engine Drain Oil and Washings.

TABLE NO. 9—AVERAGE INCREASE IN WEIGHT OF IRON (FE) IN DRAIN OIL AND WASHINGS

Full Flow	
Test No. 1	0.603 Grams
Test No. 2	0.712 Grams
Test No. 3	0.754 Grams
Average	0.690 Grams
Partial Flow	
Test No. 1	1.207 Grams
Test No. 2	1.192 Grams
Test No. 3	0.9065 Grams
Test No. 4	1.482 Grams
Average	1.195 Grams
No Filter	
Test No. 1	5.50 Grams
Test No. 2	6.31 Grams
Test No. 3	8.64 Grams
Average	6.82 Grams

conclusion of the tests with no oil filter averaged approximately six times the average weight found in the drain oil and washings from the partial flow filtration tests, while the weight of iron from the engine equipped with the full flow filtration system averaged approximately one-half the iron of the partial flow samples.

It is apparent that a "wear balance" could be established for the wear test engine. In any test the sum of the total metal removed from the piston rings and cylinder walls should be approximately equal to the sum of the increases in iron content of the oil filters used, of the lubricating oil, and of the solvent used to wash the engine interior at the conclusion of the test.

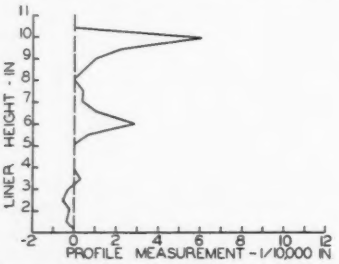


Figure 8. Average Cylinder Wear—Cylinder No. 1.

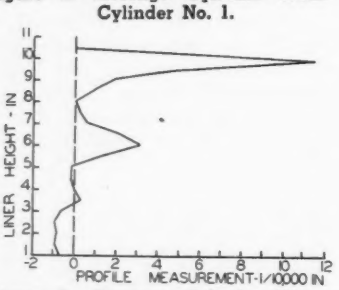


Figure 9. Average Cylinder Wear—Cylinder No. 2.

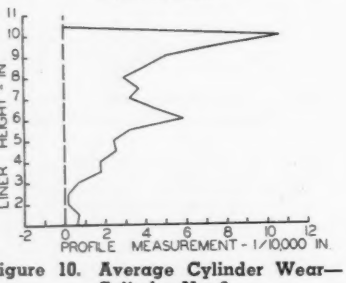


Figure 10. Average Cylinder Wear—Cylinder No. 3.

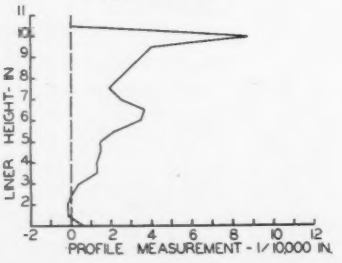


Figure 11. Average Cylinder Wear—Cylinder No. 4.

The metal removed from the piston rings can be very accurately determined, and is usually considered to be the best "yardstick" for measuring engine wear. The metal removed from the cylinder wall is practically impossible to determine quantitatively, and although the cylinder liner gauge described in Appendix A was developed at Armour Research Foundation to aid in eliminating the errors introduced by the use of diametrial measuring gages, this instrument was not designed until the test program was well under way, and the need for a better method for measuring cylinder liner wear had been demonstrated.

Typical measurements of cylinder liner wear made with the Armour profile gage are shown graphically in Figs. 8, 9, 10 and 11. These four cylinder liners were from the third "no-filter" test. In each of these illustrations the dashed ordinate represents zero wear, and in each case the profile shown is the average determined from measurements at eight equally spaced positions around the liner circumference.

It is interesting to note that while the depth of wear at various liner height positions changes slightly from cylinder to cylinder, the wear pattern is similar for all cylinders. The slight "negative" wear at the bottom of the liner is apparently due to warping of the liner.

The chemical analyses for iron in the filters, oil samples and drain oil and washings were conducted according to the Potassium Dichromate and Trace Analysis methods, respectively, and check tests made of all results. In order to be certain that the results of the chemical analyses were comparable to the engine wear results, and also to enable the observers to investigate how the filter removes iron, a study was made to determine the physical state of the iron in the drain oil samples.

Oil samples from a partial flow filtration test were examined by a microscopist who reported:

Sample No.	Hours	Particles per $Cm^3 x 10^8$
1	30	11.05
2	60	22.95
3	90	53.05
4	120	57.50
5	150	29.80
6	180	52.65
7	210	63.10
8	240	42.65
9	270	48.45
10	300	63.25
11	330	36.55
12	360	63.25

All of the samples showed rather large numbers of carbon particles, but the average particle size was less than one micron. Only an occasional agglomerate of fine particles would be larger than one micron. The fineness of these particles may be illustrated by a comparison with a mesh sieve; a 325 mesh sieve has openings that average approximately 44 microns on a side.

Carbonaceous residues from a typical oil sample were isolated in the dry state, and examined with the aid of the electron microscope. Representative photomicrographs, Figs. 12, 13 and 14, taken at magnifications of 4000 to 20,000X were made of these residues and of their diffraction patterns. A microscopical examination of a used oil sample was made according to two methods. First, the examination of a thin layer of oil showed movement of some of the particles which corresponded to the similar movement of a permanent magnet held close to the field of observation. Second, a filtered, washed and dried sample of the dried residue was dispersed in a drop of mercuric chloride on the microscope slide. In a few minutes the displacement of metallic mercury from the mercuric chloride by the metallic iron resulted in small droplets of mercury becoming visible throughout the preparation.

The diffraction pictures are evidence that the particles are predominantly graphitic carbon. The iron known to be present is not identifiable in the pictures, since differentiation would be based only on differences in particle size and shape. The large particles in the electron microscope microphotographs are probably aggregates of many hundreds of particles, and complete dispersion of the sample gives no single particles that can be unequivocably identified as iron.

Since the chemical analysis shows that there is iron present in the oil, and since some of the iron known to be present was found to be metallic iron by the microscopic analysis although the particle size and shape could not be determined under the electron microscope, the remaining problem was a determination of the quantity of iron, out of the total iron present, that existed as metallic iron.

Oil from a sample that had been analyzed according to the chemical and microscopical analyses previously described, and photographed under the electron microscope at 20,000X, was analyzed according to the method described in Appendix B.

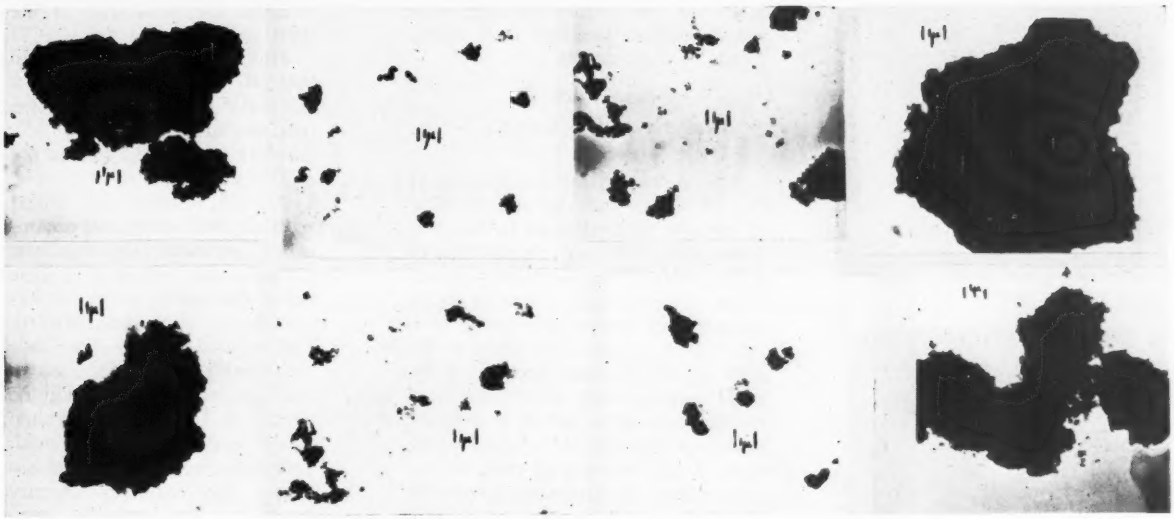


Figure 12. Electron Microscope Photomicrographs of Oil Residue-4000X.

All the iron present in a solid residue was found to be present as metallic iron, and almost one-half of the total iron was present in the solution phase, or so finely divided that it passed through No. 42 filter paper.

Conclusions

It is now established that at least one-half, and possibly more, of the iron present in the drain oil is metallic iron and, therefore, iron removed from the upper cylinder region, so the results of the analyses of the oil samples, drain oil and washings, and of the filters, are comparable with the piston ring wear figures.

The results of this test series show that within the limits imposed by the test procedure, filtering of engine lubricating oil does reduce engine wear. The test engine operated with no oil filter showed consistently greater wear rates than the same engine operated with a filter, and of the two possible methods of filtering the oil, partial and full flow filtrations, full flow is shown to be the most effective in reducing engine wear.

It is the opinion of the observers that this wear reduction is accomplished through the labyrinth action of the filter in removing iron rubbed from the upper cylinder region from the lubricating oil as the oil passes through the filter, and thus preventing this iron from being returned in the oil to the upper cylinder region to act as an abrasive. The mechanism by which the iron is removed from the oil by the filter is not completely understood, but the results of the electron microscope studies lead to the speculation that the metallic iron particles are carried in aggregates of graphitic carbon. The action of the filter surfaces in clogging with this graphitic carbon, as well as other contamination in the lubricating oil, may thus also remove the iron carried by the carbon particles.

In recognizing the limits of this investigation, it is apparent that further test work could be instituted in the direction of investigating the wear rate trends resulting from the use of different types of filters, the effects of variable engine operation, the possible relationship of wear to additive concentration and other factors. The mechanism of filter action in removing the products of wear from the lubricating oil could also receive further attention.

Acknowledgement

Credit should be extended to the Cuno Engineering Corporation for their support of this test program, along with our thanks for the understanding cooperation of Mr. C. H. Cuno and Mr. H. W. Munday of that organization who made this program possible. Special credit is due Dr. W. C. McCrone of Armour Research Foundation for his assistance in microscopic and analytical aspects of the program.

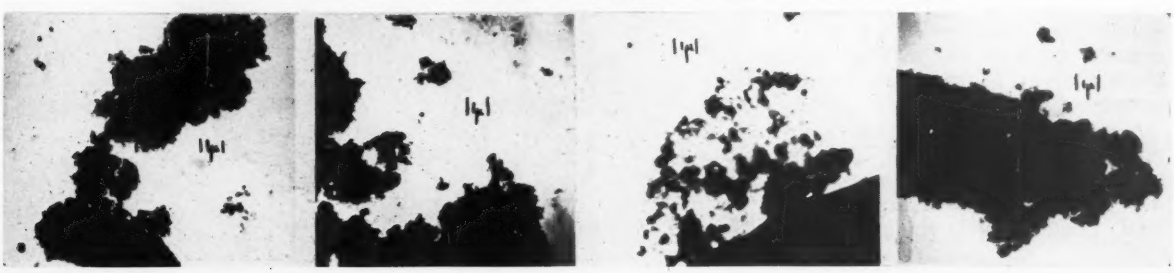
Appendix A

Cylinder Profile Measuring Gage

Figure 15 is a photograph of the equipment used in a method of cylinder wear measurement developed by the staff of the Engine Research Laboratory at Armour Research Foundation. In this method the change in profile of the cylinder wall is measured, instead of measuring the change in diameter of the cylinder bore.

The profile measurement method consists of positioning a theoretically straight surface inside the cylinder bore or liner, parallel to the cylinder wall, and measuring the variations of the length of perpendiculars from the straight surface to the cylinder wall.

Figure 13. Electron Microscope Photomicrographs of Oil Residue from Filter—4000X.



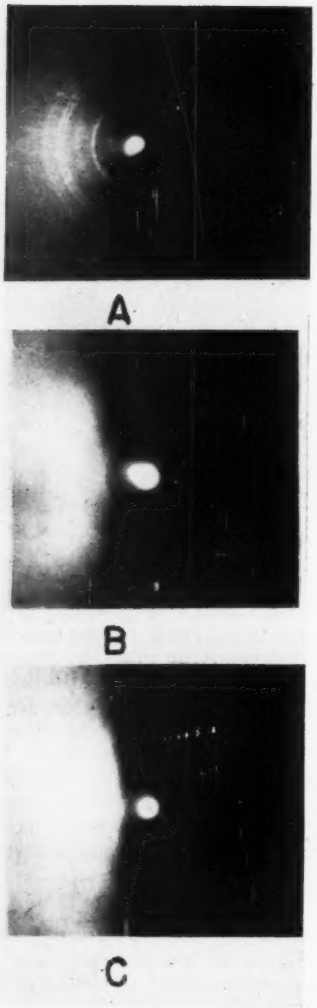


Figure 14. Electron diffraction pictures of (A) known graphite particles, (B) residue from oil, (C) residue from filter.

The dial gage is mounted in the carriage that rests on the instrument frame. The mating surfaces of the gage carriage and frame are very carefully finished, and the frame surface is machined and ground to achieve the maximum degree of straightness.

The frame is positioned parallel to the cylinder wall through the four dowel pins. Two of these pins rest on the inside surface of the liner above top ring travel, and two rest below bottom ring travel, where substantially no wear occurs. A stop contacts the liner top so that the frame is always in the same relative position of liner depth.

The profile measurements are taken at equally spaced points around the liner circumference. The dial gage is set to zero at the top land position, and readings are taken at the center of top ring travel, and at one-half inch increments of liner depth.

Appendix B

Analysis of Oil Sample for Metallic Iron

The microscopical examination of the oil sample revealed the presence of metallic iron particles by two different tests. First, an examination of a thin layer of the oil showed movement of some of the particles corresponding to similar movement of a permanent magnet held close to the field of observation. Second, a filtered, washed and dried sample of residue was dispersed in a drop of mercuric chloride on a microscope slide. Small droplets of mercury resulting from displacement of metallic mercury from mercuric chloride by metallic iron became visible throughout the preparation.

Since the metallic iron had now been identified qualitatively, the following four analyses were made:

1. Analysis for total iron in oil sample—

   The sample was weighed in a platinum crucible and carefully ashed, and the ash fused in acid potassium sulphate. This was dissolved in distilled water and the iron precipitated as ferric hydroxide by means of sodium hydroxide.
2. Analysis for total solids in the oil sample—

   After experimenting with six other solvents, the sample was weighed and dissolved in ether, filtered through a No. 42 filter paper, dried and weighed.
3. Analysis for total iron in the solid residue—

   This analysis was similar to that of No. 1, except that a sample of the solid residue was used to start.
4. Analysis for metallic iron in the solid residue—

   The solid residue was mixed with distilled water and a saturated solution of mercuric chloride, and digested a little below the boiling point for several hours, and then filtered. The residue in the filter was rinsed with hot distilled water until no more solids could be extracted. The residue was then boiled with dilute nitric acid, and refiltered to bring into solution the metallic mercury freed by the metallic iron, which is precipitated as sulphide.

The results of these analyses were:

1. Total solids in original sample 0.717%
2. Total iron in original sample. 0.127%
3. Total iron in solid residue . . 8.1%
4. Metallic iron in solid residue 8.0%

It may be concluded from these results that

1. All of the iron present in the solid residue is present as metallic iron.
2. The total iron in the original sample is 0.127%. If this amount of iron was present in the residue, there would be 15% iron in the residue, yet analyses of the residue showed 8.1%. Either one-half of the iron is present in the solution phase, or it is so finely divided that it passes through the No. 42 filter paper.

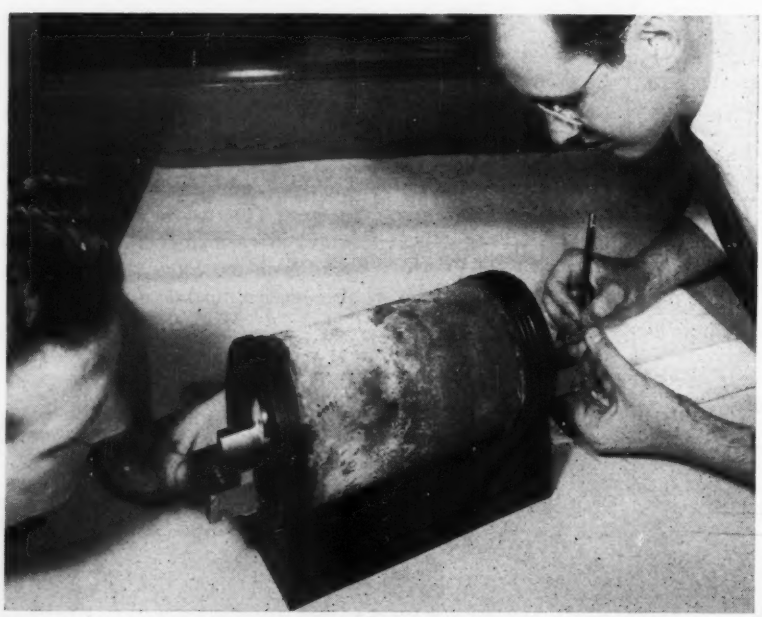


Figure 15 →

Foaming of Lubricating Oils*

By C. E. TRAUTMAN

Gulf Research and Development Company, Pittsburgh, Pa.

Outstanding results in the use of silicones as anti-foam agents in lubricating oils to conquer a war-aggravated problem are demonstrated by the author in this article. He shows how these additives, unusual in their lack of adverse effect on the functional properties of an oil, completely suppress foaming in concentrations as low as five parts per million by weight.

* * * * * * * * * *

Introduction

UNTIL recent years, foaming of lubricating oils did not cause much trouble except occasionally in such equipment as racing car engines and automotive and industrial gears. It was not until early in the war that foaming reached serious proportions in aircraft engines, naval Diesel engines, and military tank engines and gears. One of the principal causes of the foaming was the increased foaming tendency of the oils specified for use in this equipment. The detergent-type, compounded oils meeting the Army-Navy engine oil specifications (before foaming limits were applied) in general had greatly increased foaming tendency as compared with the uncompounded base oils. However, foaming difficulties were largely eliminated by the development of antifoam agents which reduce foam stability of these compounded, as well as straight mineral oils, to a minimum.

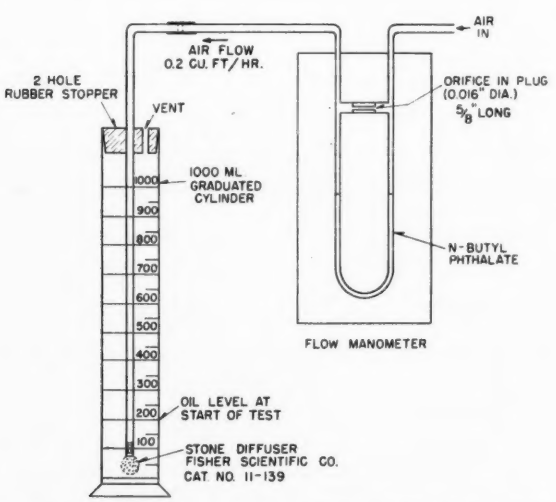


Figure 1. Foam Test Apparatus. CRC Designation L-12-1143.

In addition to their use in the Army-Navy specification oils, anti-foam agents have also found successful application in automotive and industrial gear oils, aircraft engine oils, steam turbine oils, hydraulic oils, and special industrial lubricating oils.

An empirical procedure was developed for determining relative foaming tendency of oils. This procedure involves the use of simple laboratory apparatus designed to introduce finely dispersed air at a controlled rate under the surface of the oil sample. The apparatus is illustrated in Figure 1. The test is rapid and reproducible, and correlates well with service performance.

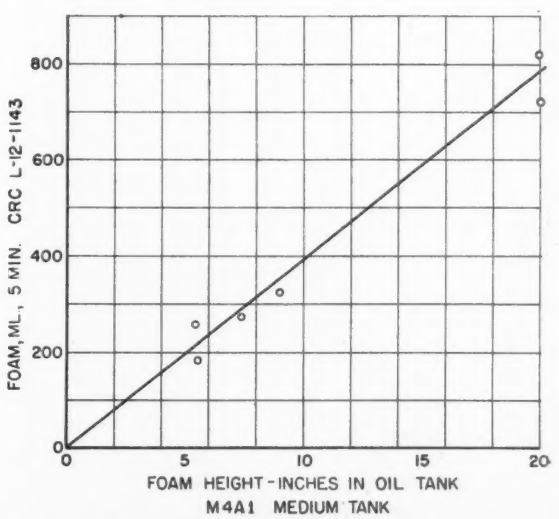


Figure 2. Laboratory and Field Foam Test Correlation. CRC Working Group on Foaming.

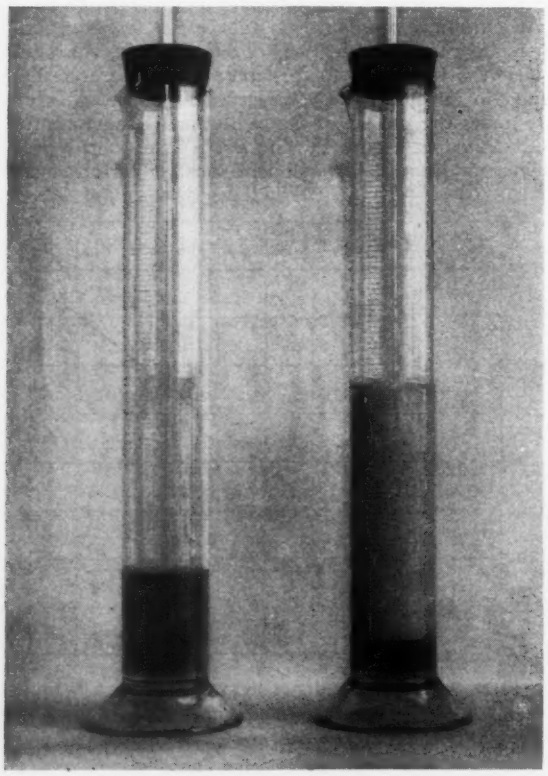
* *Presented at the First Spring Meeting of the American Society of Lubrication Engineers, Chicago, Illinois, April 5 & 6, 1946.*

Table 1—Foam Test Correlation
CRC Working Group on Foaming

Oil	Seq.	Foam Collapse ML. Foam 10 Min. After Foaming Range	Average	Max. Value Foam Collapse U. S. Army Spec. 2-104B	Rating by L-12-1143	Field Service Rating
F-15	(1)	515-660	592	(1) 300	Bad	Bad
	(2)	585-780	706	(2) 25	Foamer	Foamer
	(3)	490-685	576	(3) 300		
F-16	(1)	145-325	211	(1) 300	Non-	Non-
	(2)	0-120	46	(2) 25	Foamer*	Foamer
	(3)	150-340	229	(3) 300		
F-17	(1)	260-470	369	(1) 300	Moderate	Moderate
	(2)	455-695	612	(2) 25	Foamer	Foamer
	(3)	175-460	331	(3) 300		
F-18	(1)	0	0	(1) 300	Non-	Non-
	(2)	0	0	(2) 25	Foamer	Foamer
	(3)	0	0	(3) 300		

* Slight foamer by sequence 2.

A similar procedure was adopted by the CLR Group on Foaming. The procedure was made available by Coordinating Research Council as CRC Designation L-12-1143 in November, 1943. (Latest revision bears CRC Designation L-12-445.) Data obtained by this test correlated well with (1) field service data obtained at the General Motors Proving Grounds; (2) field service tests made at Camp Seeley, and (3) at Fort Knox; and (4) laboratory engine tests made by the U. S. Naval Engineering Experiment Station at Annapolis. The results of field service tests are compared with laboratory test results in the tabulation in Table 1. Additional field test data are shown in Figure 2, where the foam (measured in inches) that developed in the oil tank of an M4A1 Medium Tank is plotted against the foam each oil developed in the laboratory procedure.



←Figure 3.

Silicones as Antifoam Agents

In developing antifoam agents for lubricating oils, attention was directed toward additives that would do the job efficiently, and would have no adverse effect on functional properties of the oil. Of all the additives that have proved useful in reducing foaming of oils, the new and useful materials known as the silicones, and particularly the liquid products, were found to be outstanding in satisfying these two requirements. The viscous liquid silicones (dimethyl silicones are available commercially) are extremely efficient in reducing foaming of oils, and, in addition, their great stability enables them to perform under very severe conditions without loss of effectiveness. Antifoam agents containing silicones were widely used during the war to provide nonfoaming engine oils for the Army and Navy, and as far as can be determined, there were no further complaints of foaming.

One example of antifoam action is illustrated in Figure 3, which shows the behavior of two oils, one containing a silicone antifoam agent. The amazing efficiency of the silicones as antifoam agents is shown by the curve in Figure 4. The additive completely suppressed foaming in concentrations as low as 0.0005% by weight (5.0 parts per million). Even lower concentrations were partly effective; 0.000005% (0.05 ppm) reduced foaming to about 50% of that for the base oil.

The effect of elevated temperatures on the foaming

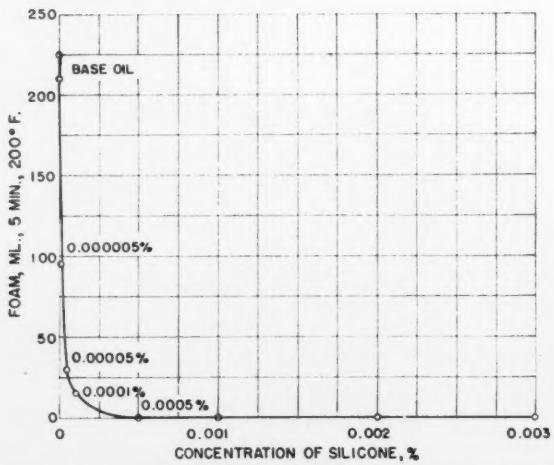


Figure 4. Effect of Silicone Antifoam Agent on Foaming of SAE 50 Oil at 200 F.

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of two typical engine oils is shown by data represented in Figure 5. The detergent oil meeting Specification 2-104B (except for the foaming requirement) shows an increase in foaming with increase of temperature. This is typical of most detergent oils which do not contain foam suppressors. Data for the high V.I. oil without a detergent illustrates the usual foaming behavior of a straight mineral oil at elevated temperature. The addition of the silicone antifoam agent eliminated foaming of either oil at all temperatures.

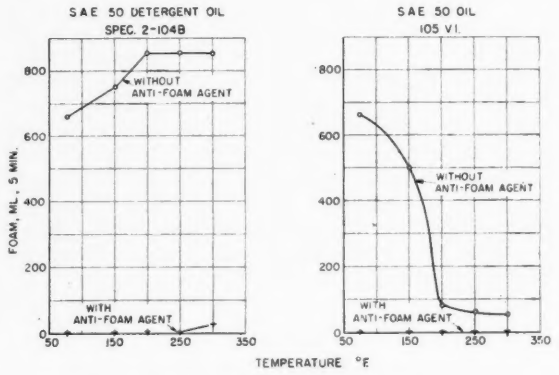

Figure 5. Effect of Temperature on Foaming.

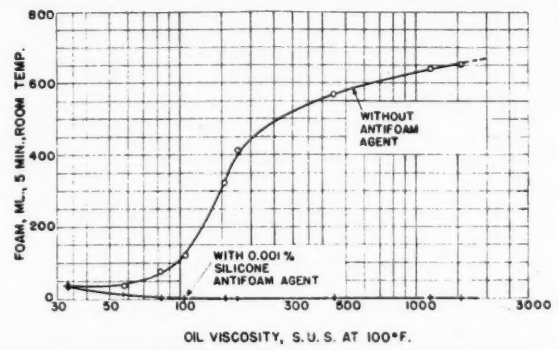

Figure 6. Foaming of Paraffin Base Oils with and without Silicone Antifoam Agent.

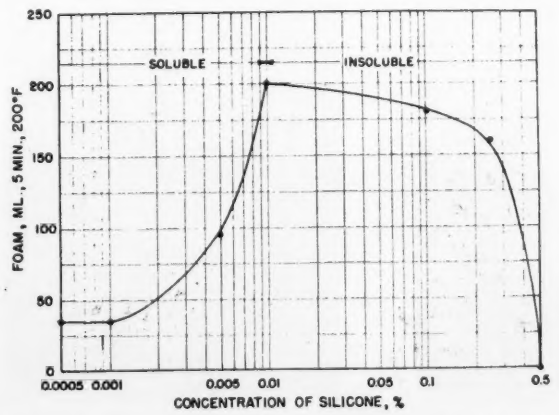

Figure 7. Effect of Silicone on Foaming of Light Oil at 200 F.

TABLE 2—EFFECT OF OXIDATION ON FOAMING
S.A.E. 50 Paraffine Base Oil (105 V.I.)
Underwood Test, 325 F Cu/Pb Bearing

	ML. Foam (5 Min.) at 200 F (CRC L-12-1143)				
Hours Oxidized ...	0	3	6	9	12
Oil	240	215	255	375	505
Oil + Antifoam Agent	0	0	0	0	0
Oil + Unsatisfactory Commercial Antifoam Agent	0	180	200	160	180

The behavior of the high V. I. oil without the detergent suggests that foaming is dependent on the viscosity of the oil. This has been found to be the case for similar types of oils. The data of Figure 6 illustrate this point. The foaming tendency of the paraffin base oils alone and with 0.001% silicone are shown. It will be noted that this proportion of additive completely suppressed foaming in all but the very low viscosity oils. An increased proportion is required to do this, although actually the foaming of these oils is generally unimportant. Of academic interest, however, is the fact that the silicones effective in the lubricating oil range actually increase foaming at low concentrations in the non-lubricating petroleum oils such as fractions below the gas oil range. Figure 7 shows the effect on a petroleum fraction corresponding in viscosity to a gas oil. A small proportion of the silicone increased foaming up to a certain concentration beyond which further additions decreased foaming. The concentration of silicone corresponding to maximum foaming also corresponds to the maximum solubility of the silicone in the gas oil. These and other data indicate that the silicone, to be effective, must be present in an amount exceeding its solubility in the oil. For this reason the liquid silicones having the least solubility in the oil are the most effective.

Since the silicones have extremely limited solubility in the normal lubricating oils, a slightly different technique must be used to incorporate the additive than is normally used to add soluble agents. The most common method is to disperse by homogenization a comparatively large proportion of the silicone into a carrier, usually a part of the same oil or a similar oil. This carrier or concentrate then can be added directly to the final oil by mild agita-

TABLE 3—EFFECT OF ENGINE OPERATION ON FOAMING
Lauson Engine ..... 1850 rpm
Output ..... 3 hp
Jacket Temperature ..... 340 F

	Crankcase Temp.	Engine Hr.	ML. Foam CRC Procedure 77 F	200 F
S.A.E. 50, 105 V. I. Oil	190F	0	625	240
		20	540	215
S.A.E. 50, 105 V. I. Oil + Antifoam Agent	190F	0	0	0
		20	0	0
S.A.E. 30, Spec. 2-104B Oil	225F	0	650	780
		216	630	100
S.A.E. 30, Spec. 2-104B Oil + Antifoam Agent	225F	0	0	5
		216	0	0

TABLE 4—EFFECT OF ANTIFOAM AGENT ON OXIDATION
S.A.E. 50, 105 V. I. Oil
Underwood, 325F Cu/Pb Bearing

	Neut. No.	Naptha Insol. Sludge Mg/10 gm	Viscosity S.U.S. At 100 F	Bearing Corrosion Gms Loss
		Oxidized 6 Hours		
Oil	0.83	2.7	1208	0.030
Oil + 10 Times Recommended Conc. Antifoam Agent	0.94	2.6	1190	0.015
		Oxidized 12 Hours		
Oil	13.8	4.0	2945	0.198
Oil + 10 Times Recommended Conc. Antifoam Agent	12.5	3.2	3039	0.103

TABLE 5—EFFECT OF ANTI-FOAM AGENT ON OIL PROPERTIES DURING ENGINE TESTS
Lauson Engine .....1850 rpm
Output .....3 hp
Jacket Temperature .....340 F

		Oil Properties		
Crankcase Temp. F	Engine Hours	Neut. No.	Naptha Insol. Sludge Mg/10 mg	Viscosity S.U.S. 100 F
S.A.E. 50, 105 V.I. 190F.	0	0.03	0.4	1100
	10	1.24	10.5	1210
	20	2.95	11.0	1493
S.A.E. 50, 105 V.I. 190F.	0	0.03	1.7	1143
+ Antifoam Agent	10	1.20	7.3	1165
	20	3.31	9.9	1473

tion in the same manner that soluble compounds are added.

The inherent stability of silicones is reflected by the persistence of the antifoam agent under severe conditions of oxidation as shown in Table 2. The foaming tendency of the oil without additives increased with oxidation, while the oil containing 0.001% silicone remained completely non-foaming under the severe conditions of Underwood oxidation at 325F.

Evidence of the stability of the silicone antifoam agent under severe conditions of engine operation is brought out in Table 3. Foaming of the oil was eliminated under all conditions of the Lauson engine test shown. In other tests, not illustrated here, the action of the antifoam agent has persisted far beyond the usual life of the oil.

It is unusual to find an oil additive that is as efficient for its intended purpose as the silicone antifoam agent, and that at the same time does not adversely effect other functional properties. Typical data from laboratory tests are shown in Ttble 4 and Table 5. The Underwood oxidation data in Table 4 indicate that the silicone has no adverse effect either on the course of oxidation or on bearing corrosion. Similar data, obtained in Lauson engine tests, are listed in Table 5. The results of extensive tests in laboratory wear machines, laboratory wear machines, laboratory test engines, and full-scale automotive and aircraft engines indicate that the silicone antifoam additive has no detrimental effect on the oil. The excellent service record of the additive confirms the laboratory results.

As mentioned before, the antifoam agent aids in the reduction of aeration. Obviously, the agent cannot prevent aeration, but it does tend to get rid of the air more rapidly. The agent promotes coalescence and junction between two gas bubbles of moderate size to form a larger bubble which escapes more rapidly to the free surface where the antifoam action breaks the bubble. This point is illustrated by the photographs in Figure 8 where aeration has been produced by pumping, under identical conditions, samples of an oil with and without added antifoam agent. The sample on the left containing the antifoam agent shows considerably less aeration. In an aircraft engine during a flight test the silicone reduced aeration of the oil sufficiently to cause an 8% increase in the engine oil pressure at high altitude. In laboratory bench tests, using a gear pump set-up to produce aeration, the actual air held entrained in oil containing the antifoam agent was reduced to about half of that held by the oil without antifoam agent. It might be mentioned that while the total amount of aeration was decreased in an oil containing the silicone, under some conditions an increase in the number of very fine bubbles was noted.

Conclusion

Some of the basic factors involved in the design of lubricating systems to reduce aeration and foaming are:

a) high free-surface-to-volume ratio,
b) low viscosity of lubricant,
c) time for bubbles to escape,
d) time for bubbles to collapse on free surface.

The use of a lubricant containing antifoam agent minimizes the influence of the last two factors on design of lubricating systems where aeration and foaming are involved. Thus, in addition to improving the operation of existing equipment, non-foaming oil should aid designers in creating more efficient lubricating systems.

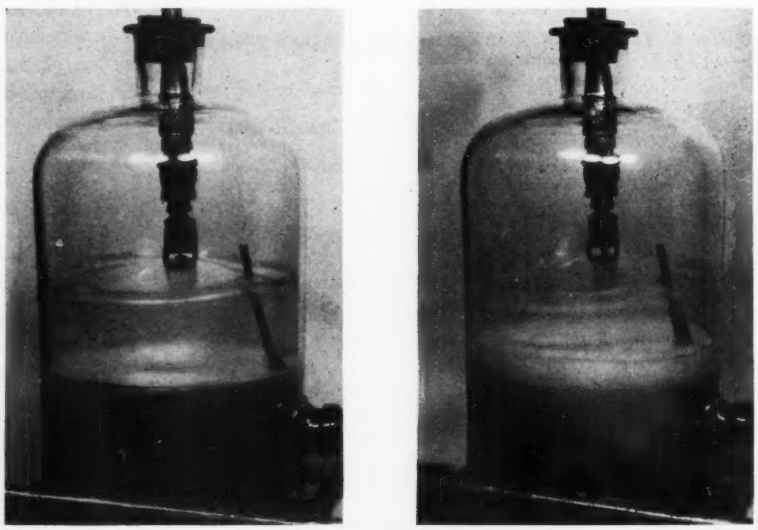

Figure 8

Some Observations on Automotive Engine Lubrication*

By ARTHUR F. UNDERWOOD

Head, Mechanical Engineering Department—5
Research Laboratories Division, General Motors Corporation

This paper introduces the theory that for certain applications, sliding surfaces approaching optical flatness in smoothness are not wholly desirable. The lubrication requirements of various engine parts such as rings, piston skirts, wrist pins, connecting rod and main bearings and valve mechanisms are thoroughly discussed. Sludge formation is covered, as well as the practice of using light viscosity oils. An extensive bibliography is appended.

Introduction

THE lubrication of automotive engines has been developed as an art rather than as a science. Even today most progress is being made by "trial and error." While a knowledge of the laws of lubrication and associated metallurgy and chemistry is essential, scientific formulas are not generally used. This is largely true because we do not know the constants for the equation, and often we do not know the equation.

However, experience has shown the limits within which we can operate our mechanisms. Thus, if a babbitt bearing is loaded beyond 2000 psi, it will have too short a life. If an uninhibited oil is continuously operated either at 300 F or at 110 F, it will likely ruin the engine in short order.

The practice of automotive engine lubrication is thoroughly reported in many engineering papers. This general article considers several of the fundamental concepts of surfaces and their lubrication, and then demonstrates how these concepts apply to engines. In many instances, the application is very obscure, and we will have to recognize the fact that much of our knowledge is empirical.

General Principles

At least two theories are given for the friction developed by two surfaces rubbing in contact. One is the "roughness" theory, which says that the interlocking of the surface projections causes frictional forces. In this case the surface may be improved by making it smoother, or by making it of a weaker material which fractures or deforms easily. A second theory is that when metal surfaces become sufficiently close together their fields of attraction cause an adherence. In fact, when the conditions become severe these forces become large enough to cause welding of the two sliding parts.

In practical engineering, the metal surfaces are "contaminated" with oxide films, thin oil films, and adsorbed gases. These factors decrease the friction and scoring compared to clean dry surfaces, but are very variable. Thin oil films give "boundary" lubrication, which is probably the cause for most engine difficulties. Oiliness and EP additions may have tremendous effects on the operation of certain surfaces under boundary film lubrication. Oiliness is generally understood to be developed by a polar chemical compound which tenaciously adheres to the metal, to reduce scoring and seizures. EP agents are activated by the heat of friction to develop new surface layers which resist scoring and seizure. Both of these materials are effective only when the type of operation is correct. When testing for their usefulness, one must be certain to reproduce all conditions under which they will be used.

At the other end of the scale is full fluid film lubrication. When the motion characteristics of the two surfaces are suitable, they will be separated by a complete oil film which is quite independent of the metals. Formerly, engineering practice for lubrication rested on the belief that there must be a relative sliding motion to generate a hydrodynamic film. In addition, the accepted fact was to have the two areas at a slight angle to one another, thereby producing a wedge of oil which was the basic reason for the hydro-dynamic oil film. Recent work on this subject has demonstrated how a true oil film can be properly produced and will maintain engine forces, without the benefit of a wedge film. The film can be generated by a load which is rotating in direction or alternating in direction, with no angular velocity of the shaft. Even flat parallel surfaces will support a load, if a reversing cyclic load is applied.

Turning now to the geometry of the lubricated surfaces the objective of many engineers for years was to get continuously smooth surfaces of nearly optical flatness. But after the technique for making surfaces was developed, it was found undesirable to employ smooth surfaces in a great number of instances. As one example, cylinder walls were being made with a smoother and smoother finish as manufacturing technique progressed. A reversal occurred when certain types of rougher surfaces were found to give better results. A different variety of desirable roughness is found in the interrupted surface. Here the high areas are relatively smooth, with interspaced depressions as shown in Figure 1. Engineering history as far back as

* *Presented at First Annual Meeting of the American Society of Lubrication Engineers, Chicago, April 5, 1946.*

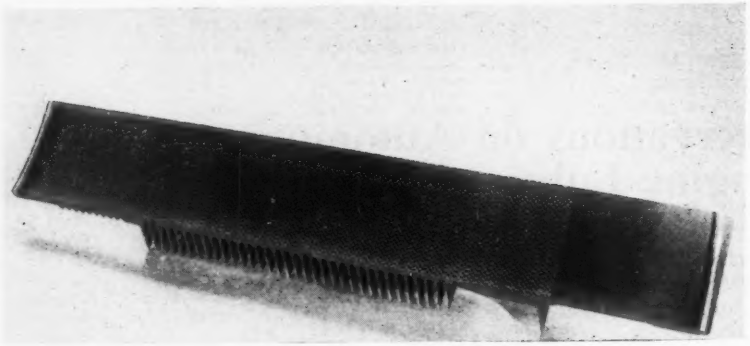

Figure 1. An example of interrupted surfaces applied to a cylinder barrel.

1885, records the fact that this was known to give superior results. In a discussion of Tower's famous second report, Edward Reynolds said, "There were many cases of slide-bars and rubbing surfaces of that kind, which worked on for ever so many years before the scraper marks were gone; and then all at once they began to cut, because the scraper marks were gone. It did not do to have exceedingly well-fitting surfaces, for high speeds at any rate."

Oiling systems vary extensively from the hit-and-miss type, through wick oiling, splash type, and on up to complete pressure lubrication. For some obscure reason, many people feel that this is the order of reliability, effectiveness, and efficiency. This is not always true. For many inaccessible locations splash oiling gives the best results. Pressure lubrication of valve stems or cylinder walls would bring on new and difficult problems, perhaps with no improvement at all in the successful operation of the automotive engine.

It is also proper to consider bearing metals in a discussion of lubrication, because practically no surfaces are continuously separated by an oil film. If they were, only the hardest metals to resist wear and fatigue would be used.

The question is often asked, "What is a bearing material?" The only good answer we know is the rather trite one: "The material which works best in a particular location." No one material is suitable for all applications. We frequently use an automobile engine connecting rod as an example. Babbitt in the big end has been found to give the best overall results, but bronze is employed as wrist pin bushings. Both of these non-similar metals make excellent bearings as used, but when they are reversed, neither is suitable. For such reasons, each application in an automotive engine may require a particular metal.

Engine Lubrication

Consideration of the cross-section of an automotive engine will show many types of surfaces to be lubricated according to the principles previously discussed. Each part will be treated separately, but in so doing a word of caution is injected: As in every engineering problem, there is frequently more than one answer. Then, too, what may work in one engine for a main bearing, as an example, may not be satisfactory for another engine main bearing. Therefore, the observations in this discussion are based on a general picture of engine lubrication.

Piston Rings

Piston rings, piston thrust areas, and their adjacent cylinder walls, operate mostly under boundary oil film conditions. The loads, speeds and relative position of the surfaces are not conducive to a continuous oil film. However, there is some evidence that an oil film can sometimes be formed during the middle part of the stroke, when the velocity is highest.

These thin oil film conditions give rise to wear and scoring, especially at the top edge of the piston travel. To get more oil between the surfaces it has been found necessary to have interrupted surfaces. As previously mentioned, the present practice is to use a cylinder bore which is relatively rough or which has crevices as in the case of chromium plate.

Piston rings for high output engines have given successful results until they are worn smooth, when they will quickly score. Surface treatments of oxide, or a groove filled with tin or bronze are well known improvers. Such metals add a small amount of non-scoring material.

Additions to the oil appear to have little or no effect on rings and cylinder walls under present day conditions.

A very important point is the operating temperature of the rings. Proper piston design, including oil cooling for heavy-duty, has been demonstrated to prevent ring sticking and plugging. If the temperature behind the top ring groove is held between 350 to 400 F, we have found no trouble in ring operation.

In general, most ring and cylinder wall development is empirical. Many machines have been developed to investigate these problems, but their success has not been sufficient to allow an engineer to predict what rings to use in a proposed engine.

Piston Skirts

The conditions occurring on the piston thrust areas are not as severe as on the rings. But the oil film is so erratic and inadequate that better surfaces than steel to cast iron, cast iron to cast iron, and aluminum to cast iron are generally required. Lead alloy or tin plating, or phosphate coating on steel and cast iron, and an anodic treatment or tin plating on aluminum, are usually employed.

It is interesting how tin plating is said to have been started. The first and only engine of a new model was due on a certain date. The day before it was discovered that all the pistons were undersize. A stroke of genius brought out the suggestion to fill the gap with tin plate. The resulting pistons ran so well that tin plating has become almost universal on iron alloys. This is typical of one type of good engineering—recognizing a useful accident.

A frequent cause for poor lubrication conditions on piston skirts is the distortion which develops high local pressure. Heat or load may be the source of this difficulty. The first can only be cured by adequate cooling. Load distortion is a design problem, usually brought about by the inclusion of the wrist pin bosses in the piston skirt. Also, the head tends to wrap around the wrist pin. By designing the head so that the load is uniformly transferred between head and pin, this can be reduced to a minimum.

Wrist Pin

The lubrication of a four-cycle wrist pin offers no problem, provided a sufficient supply of oil is available. The alternating force between the bushing and the pin generates a true oil film. Before the oil can be squeezed out completely on the lower surface of the pin, the load reverses to the top surface and proceeds to squeeze that oil out.

Such squeezing action generates a hydrodynamic film pressure to support the load. The oscillations of the rod are quite unimportant.

Two-cycle wrist pins are much more difficult to lubricate, because the forces are nearly always in only one direction. No squeeze oil film action can occur. Oil must be dragged in by proper grooving. Helical grooves, spaced slightly less than the angle of rod oscillation, have given the best results.

Because the rubbing velocity is low and the loads high, bronze is generally installed. Very heavy duty two-cycle engines have used silver.

The best surface for "squeeze oil film" lubrication is one which is as smooth and continuous as possible. Therefore, most pins have a lapped finish.

Connecting Rod Bearings

Connecting rod bearings have to withstand high loads and high speeds. A load of one ton per square inch of projected area is not uncommon at a rubbing speed of 2500 feet per minute. Such bearings can operate so satisfactorily because of the oil film established by the relative motion of the journal and the bearing. This action is so well known that there is no need to discuss it further.

In addition, such dynamically loaded bearings have an augmented oil film through the unusual action of the forces and motions. Another article describes this investigation.[12]

It has long been recognized that oil grooves are not necessary in these bearings. An oil supply of sufficient rate to keep the clearance volume full, is all that is required. But because of the back pressure produced at the main bearing, the engineer must be sure the pump will maintain a high enough pump pressure at all times. The back pressure can be readily calculated as the centrifugal force of the effective oil column within the main bearing, as shown in Figure 2.

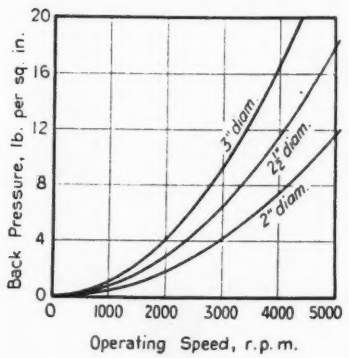

Figure 2. Back pressure developed at main bearings through centrifugal action of oil in drilled hole in crankshaft.

Another recognized fact is that connecting rod bearings do not "burn out," unless the oil supply fails. Most burned out bearings fail by cumulative fatigue, which reduces the effective area until an oil film is no longer supported.

As pointed out previously, if a continuous oil film separated the crankpin from the bearing there would be no problem of bearing material. Even the most perfectly lubricated bearing needs a bearing material, in order to live under the conditions of occasional metal-to-metal contact. Alloys of lead, tin, and cadmium, with copper-lead for heavy duty, are the most suitable at the present time. Many engineering papers are available on the problems of connecting rod bearings.

Just before the late war, one of our automotive divisions made great progress in lengthening the life of connecting rod and main bearings. A babbitt metal was used in the location. The fatigue life of this metal is very greatly influenced by temperature. It was found that by using a special finish on the journals, fatigue life could be greatly extended. A rough grind, followed by a slight polishing with a fine abrasive paper, gives an interrupted surface with oil pockets. These pockets reduce the viscous friction and make the bearing run cooler, thereby extending fatigue life.

Dirt is an important problem in the lubrication of connecting rod bearings. Metal particles are continuously being worn off and deposited in the oil. Dirt, such as sand, is introduced down past the pistons from the combustion chamber. The crankcase ventilation system, is an additional point for the entrance of foreign material. Fortunately, however, much of this is deposited in the bottom of the oil pan and our automobiles run very satisfactorily. However, the portion of dirt which goes through the bearings may cause much trouble by wearing and scoring the pins. This is another reason for using a soft bearing metal, to provide a means for embedding the dirt. If conditions are severe enough, rapid wear and scoring will develop. The question of oil filters is the subject of much debate. Certainly, thousands of automobiles without filters run a distance equal to several times around the world before even .002 in. undersize bearings are required.

Main Bearings

The observations on connecting rod bearings also apply to main bearings. There are two major differences, however. The lubricant for the main bearing does not have to overcome a critical back pressure. And the high centrifugal force on the oil in the clearance volume of a connecting rod is not present in a main bearing.

Yet the conditions in main bearings are quite frequently more severe. The inclusion of a groove to feed oil to the connecting rod, divides the width in two narrow lands. Lubrication always is more difficult with the more unfavorable width-to-diameter ratio. This reduces the load carrying capacity of the oil film. In two-cycle engines, the main bearings can have the groove in the upper half of the bearing, by using a cross oil hole in the crankshaft. This leaves a continuous lower half on which the heavy uni-directional load is imposed.

Some crankshafts are quite flexible, and produce a slope of an appreciable angle at the main bearing. The main bearing support is relatively rigid. Edge loading occurs to give metal-to-metal contact. If the anti-friction and conforming qualities are not sufficient, trouble is inevitable. White metals, and copper-lead to a degree, are used to allow this adjustment.

In contrast, a connecting rod column is very flexible. When the shaft slopes at a crankpin, the column adjusts for the distortion.

The rate of oil flow required to merely lubricate a rod or main bearing is surprisingly low. A reduction from one-fourth to one-tenth of the normal rate will maintain the essential lubrication oil film. However, investigations have shown the oil flow to be the route by which most of the generated heat is removed from a bearing. An increase in the oil flow will reduce the bearing operating temperature. Thus, slightly thicker oil film and longer fatigue life of the bearings are achieved.

Valve Mechanism

A small amount of oil—even to the extent of the mist in the crankcase—will suffice.

In fact, considerable attention must be paid to stop an excess of lubrication from running along the valve stem. The valves run suffi-

ciently hot to cause coking of the oil. When the deposits become thick enough the valves will stick, causing erratic operation of the engine.

Engineers endeavor to control such cracking of the oil by design of the valve guide. It has sometimes been found to be effective to extend the guide into the passage, to act as a shield for the stem. Counterboring of the guide has occasionally improved the lubrication of the part.

Lubricants

Perhaps no other one subject has been given more attention in automotive engineering papers than the lubricant which is poured in the oil sump. It is intended to point out only some of the accepted observations.

The most important development in recent years has been the increase in high temperature stability. This began about twelve years ago when the corrosion of cadmium and copper-lead bearings became serious. The addition of proper chemical inhibitors extends the time before acids, varnish, and sludge develop within the oil, as shown in Figure 3.

Detergents are another addition agent added to keep the parts clean of sludge and varnish. Certain heavy duty engines, running in the region of maximum output, will have a very short life if improperly treated lubricants are used.

Without these chemical improvers, the sludge and varnish may build up in the oil system, and on the moving parts until the parts fail to function. Sludge may plug up oil systems and piston rings. Varnish may fill up clearances until a hammering is the only method of taking the pieces apart. When acids are produced by the oxidation of the oil, corrosion of copper-lead, certain bronzes, lead base alloys, and cadmium, will be dissolved entirely or partially. At one time, it was possible to start on a new filling of oil, run 800 miles at high speed, and have the bearing metal dissolved from the steel backs.

Low temperature sludge is a soft mass which comes from winter operation. Water condenses in the sump and is not removed on short runs by the crankcase ventilator. An emulsion with the oil is produced. It will plug up oil systems and fill up cavities, such as the valve mechanism compartment.

It was formerly believed necessary to use only heavy oils for satisfactory engine lubrication. But to enable better winter starting, light viscosity oils were developed. These oils gradually came into popularity when they were discovered to give better lubrication. Today, many cars utilize SAE-10 the year around. We have never seen an engine which was injured by low viscosity oil, if the lubrication system continued to operate. If leakage is greater than the pump can take care of, a failure will result. During hot weather, or at sustained high speed, a higher viscosity oil is suitable; especially for reducing noise and oil consumption of the older engines.

At intermediate operating temperatures there may still be trouble from sludge and varnish in some engines, even though an oil that does not form sludge is used; and even though the temperatures are high enough to avoid the sludge caused by water. This sludge and varnish may be caused by the gasoline. It has been found that some gasolines will produce sludge and varnish, and other gasolines will not. There are no generally recognized laboratory tests to distinguish between these two types of gasoline. However, the gasoline that will not produce sludge and varnish can be distinguished from the one that will by suitable engine tests.

How often should the oil be changed? There is no answer to this question because engines are used under such a variety of operating conditions. There is no way the car owner can tell definitely for himself, as he can when he needs his shoes resoled. Perhaps the best guide is to follow the manufacturer's recommendations contained in the instruction book.

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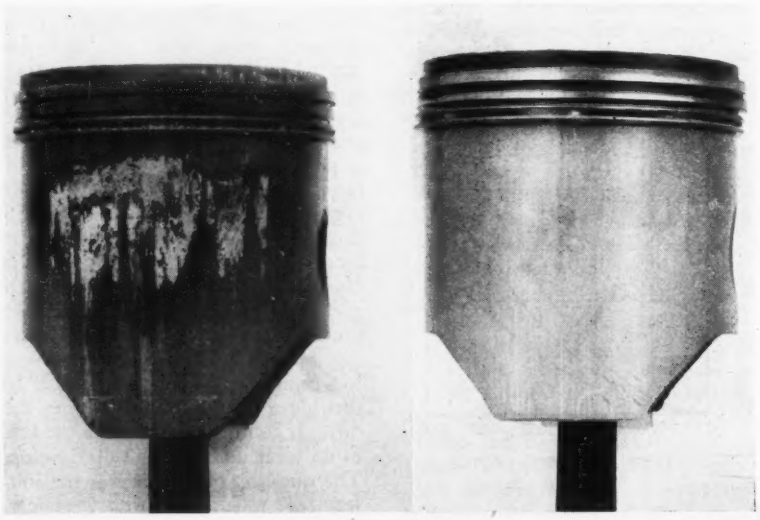


Figure 3. Effect of oil quality. The left piston has sludge and varnish while the right piston is clean when run under the same conditions.

Properties and Uses of Some New Synthetic Lubricants*

By J. M. RUSS, Jr.,

Carbide and Carbon Chemicals Corporation

This paper is the most definitive yet to appear on two series of synthetic lubricants, one being insoluble and the other soluble in water. Viscosity-Temperature charts and tables of physical properties for both series are given.

IN chemistry, the word "synthetic" denotes products which are built-up by chemical processes from simpler compounds or elements. Such processes, known as syntheses, make possible the production of many products which occur in nature, as well as others which have never been known to exist. In recent years, we have heard much about synthetic products such as rubber, resins, chemicals, and drugs. Synthetic lubricants have not been so well known, but recent developments have indicated that interesting materials can be produced.

The synthetic lubricants to be described herein are synthesized from natural or other hydrocarbon gases as the raw materials. They contain no petroleum oils, and they differ from these oils chemically. These products are superior to and are chemically different from the synthetic lubricants developed in Germany during the war. At the present time, two series of these synthetic lubricants are being produced. One series, which is essentially insoluble in water, is designated by the symbol "LB", followed by a number representing the viscosity at 100F in Saybolt Universal Seconds. The other series, the members of which are soluble in water at room temperature, is designated by the symbol "50-HB," similarly followed by a number designating the Saybolt viscosity at 100F. Both series are being produced and marketed under the trade-mark "Ucon" by Carbide and Carbon Chemicals Corporation. "Prestone" Motor Oil, which is being marketed for passenger car, bus, truck and tractor engine lubrication by National Carbon Company, Incorporated, is identified with the LB series.

These synthetic lubricants were developed by Units of Union Carbide and Carbon Corporation. The original work was carried out at the Mellon Institute of Industrial Research by the Organic Synthesis Fellowship, which is sponsored by Carbide and Carbon Chemicals Corporation. Further development of these products has been conducted, not only by the Organic Synthesis Fellowship, but in the laboratories of Carbide and Carbon Chemicals Corporation at South Charleston, West Virginia, and in the laboratories of The Linde Air Products Company at Tonawanda, New York, where automotive research work in connection with anti-freezes and other automotive products has been conducted for many years.

Properties of the Lubricants

The lubricants of the LB and 50-HB series may be prepared in any desired viscosity by controlling the reaction employed in the manufacturing process. It is not necessary to blend higher and lower viscosity oils as is the general practice in preparing certain SAE grades from Neutral and Bright Stock in the oil industry. However, blends of the synthetic products can be made if desired. The high viscosity indices, characteristic of both series of lubricants, is inherent and not dependent on viscosity index improvers.

Because of the viscosity-temperature relations of these synthetic lubricants, classification into SAE viscosity grades is difficult. For example, one of the synthetic lubricants having a viscosity of 300 Saybolt Universal Seconds at 100F is, according to the SAE classification, a SAE 20 oil but at 210F this same lubricant is comparable to most SAE 30 oils. (See Figure 3.) The slope of the viscosity-temperature curve of these synthetics varies somewhat with the viscosity, the slope tending to decrease as the viscosity of the product increases. Figures 1 and 2 show the viscosity-temperature properties of some of the lubricants of the LB and 50-HB series.

These synthetic lubricants contain no wax or any additives to depress the pour point. The pour point as determined by ASTM method D-97-39 is a stable pour and can be reproduced after repeated temperature cycles. Flash and fire points compare favorably with mineral oils, although in the lower viscosity range, below 140 S.U.S. at 110 F, the flash points are higher than for equivalent-viscosity petroleum oils. Auto-ignition temperatures are somewhat higher than those of petroleum oils of equal viscosity. The low carbon residue values exhibited by these synthetic lubricants is probably indicative of low carbon formation which has been observed when they are used to lubricate internal combustion engines.

The oxidation products of the synthetic lubricants are for the most part low-molecular-weight volatile

* *Presented at the March 15th, 1946, meeting of the New York Section of the American Society of Lubrication Engineers.*

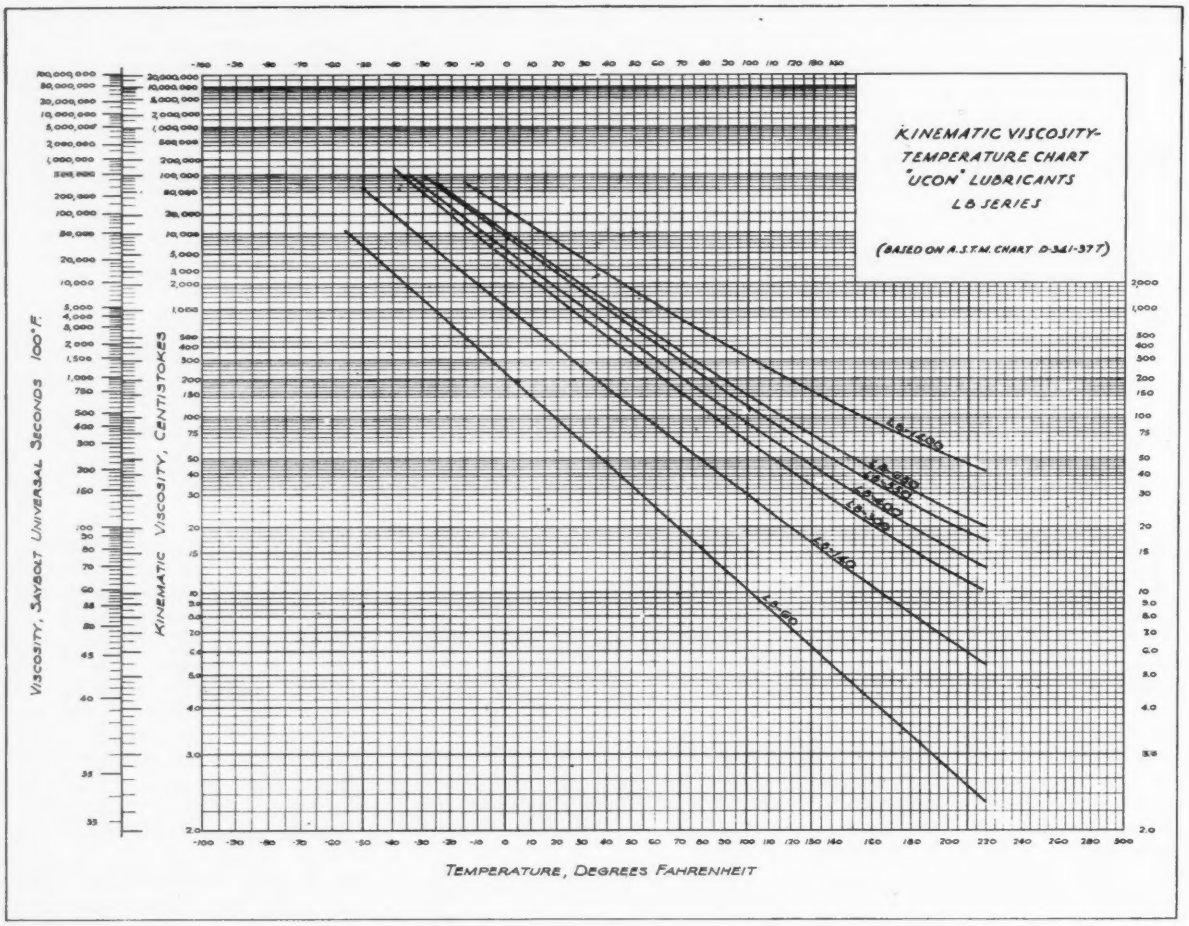


Figure 1. Viscosity-Temperature Properties—LB Series.

compounds, while in the normal process of oxidation of mineral oil, non-volatile products are formed which eventually convert to oil-insoluble sludges, gum and varnish. In the case of the synthetic lubricant, insoluble oxidation products which tend to foul an engine are not formed, and this factor is responsible for negligible increase in the viscosity of the lubricant with use.

Both the LB and 50-HB series are soluble in a variety of organic solvents. The 50-HB series is quite soluble in water at ordinary temperatures, but the water solubility decreases with increase in temperature. The LB series is soluble to a limited extent in petroleum oils at ordinary temperatures, the solubility varying with the viscosity and type of oil, the viscosity of the synthetic lubricant and the temperature. The LB series is soluble in gasoline and kerosene. At elevated temperatures the LB series becomes quite soluble in petroleum oils. (See Figure 4.) The 50-HB series is less soluble than the LB series in petroleum oils. The LB series has a solvent action on most of the oxidation products of petroleum lubricating oils and fuels. Both series have little or no effect on natural and synthetic rubbers.

Wear, Oiliness, and Film Strength

Wear data indicate that the synthetic lubricants are comparable to high-grade petroleum products in the overall factors contributing to wear characteristics under conditions so far studied. Data from laboratory test machines indicate that the "oiliness" of the synthetics is in about the same general range as uncompounded petroleum oils. "Film strength" tests on several test machines indicate that the synthetics have greater load carrying capacity than uncompounded petroleum oils of comparable viscosity. The 50-HB series have somewhat greater "film strength" than the LB series. By the use of suitable additives, improved wear, "oiliness" and "film strength" properties may be imparted to the lubricants. Extreme pressure properties may also be obtained by the use of additives chemically similar to those used with petroleum oils. Some of the additives used in petroleum oils are not suitable for use in the synthetics because of solubility and other considerations.

LB Series

Physical data for some of the common viscosity grades of the LB series are given in Table I.

The LB series, because of its special properties, is best suited for the lubrication of machinery in general, including internal combustion engines. Two of the lubricants listed in Table I, LB-300 and LB-550, have been extensively investigated as lubricants in automotive and aircraft engine use respectively.

Automotive Use of LB-300

Lubricant LB-300 (the "Prestone" Motor Oil grade) was tested in a great many engines on the dyna-

mometer stands and operated over two million miles in various types of automobiles and trucks under varying conditions. During this investigation, new engines as well as engines having varied petroleum oil history were used in tests up to 70,000 miles per vehicle. The following observations were made in this work:

(a) Clean engines remained essentially sludge and varnish free.

(b) Engines which contained deposits from previous use of petroleum oil were gradually cleaned during operation on the synthetic.

(c) Satisfactory low-temperature cranking and starting were experienced in engines operating in low-temperature areas.

(d) Combustion chamber deposits and spark plug fouling, where previously experienced with petroleum oils, was reduced.

(e) Average lubricant consumption compared favorably with petroleum oil consumption.

(f) Oil changes were dependent on external contamination and dilution rather than upon lubricant deterioration.

(g) Due to the inherent properties of the synthetic, the viscosity change due to oxidation and thermal decomposition was slight even under long mileage operation.

(h) Commercial filters of various types improved the performance of the lubricants by removing solids such as dirt, metal filings, and lead compounds from the fuel.

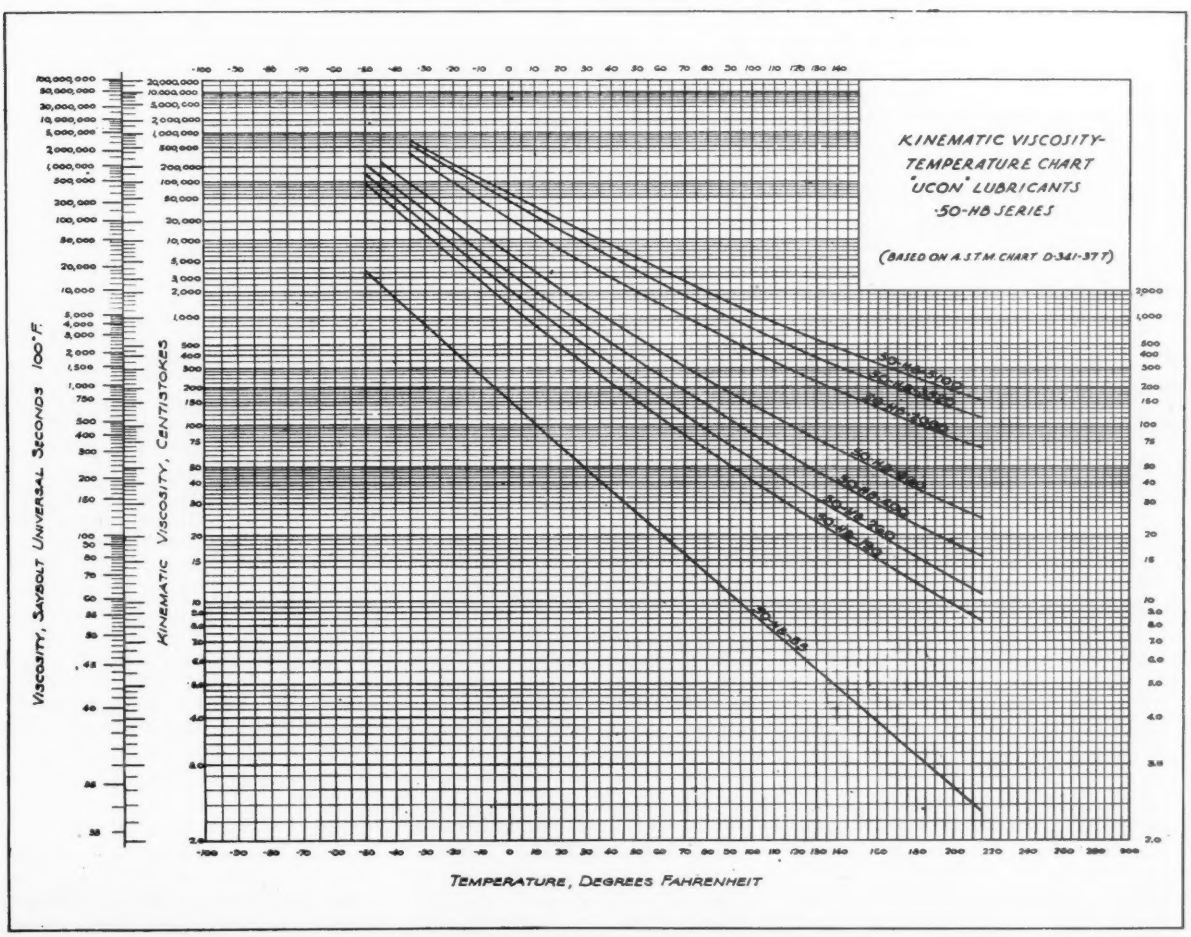
(i) Wear of engine parts and bearing corrosion with the synthetic were comparable to experience with the best petroleum oils.

(j) No "mayonnaise" or "winter sludge" type emulsions were formed

TABLE I—PROPERTIES OF "UCON" BRAND LUBRICANTS—LB SERIES

	LB-140	LB-300	LB-400	LB-550	LB-650
Viscosity, Saybolt Seconds @ 210F.	45.5	62.7	74.3	91.9	107
100F.	140	300	400	550	650
0F.	4960	18380	27600	40800	50500
—30F.	42100	183000	284000	444000	.....
—50F.	265000	.....	.....	.....	.....
Viscosity, Centistokes @ 210F.	5.9	11.0	14.1	18.5	22.0
100F.	29.8	65.0	86.6	119	141
0F.	1080	4000	6000	8900	11000
—30F.	9200	40000	62000	97000	.....
—50F.	58000	.....	.....	.....	.....
V. I. (A.S.T.M. D-587-41)	147	142	142	140	140
Pour Point (A.S.T.M. D-97-39), F.	—50	—40	—35	—30	—25
Density @ 210F. (g./cc.)	.921	.933	.936	.939	.940
Density @ 100F. (g./cc.)	.966	.979	.983	.985	.986
Specific Gravity @ 60F.	.983	.997	1.001	1.003	1.004
Gravity °API @ 60F.	12.5	10.5	9.7	9.5	9.4
Flash Point (A.S.T.M. D-92-33), F.	440	470	485	510	525
Fire Point (A.S.T.M. D-92-33), F.	510	570	580	580	580
Carbon Residue (A.S.T.M. D-189-41)	Less than .01%				
Ash (A.S.T.M. D-482-43-T)	Less than .01%				

Figure 2. Viscosity-Temperature Properties—50 HB Series.


KINEMATIC VISCOSITY-TEMPERATURE CHART "UCON" LUBRICANTS 50-HB SERIES
(BASED ON A.S.T.M. CHART D-341-37T)
VISCOSITY, SAYBOLT UNIVERSAL SECONDS 100°F.
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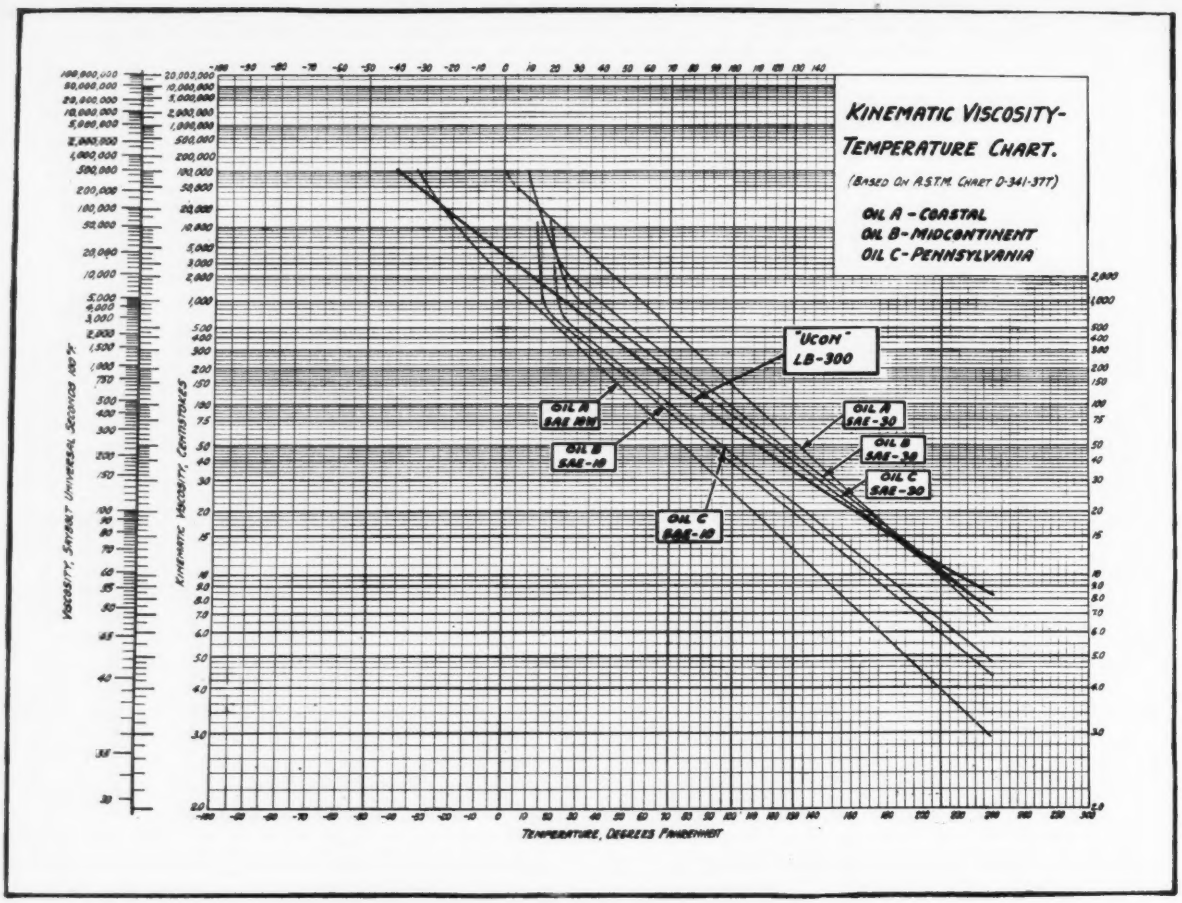


Figure 3. Kinematic Viscosity-Temperature Chart.

in engine crankcases under conditions ordinarily considered favorable to their formation.

(k) No clogging of oil screens was observed in over one hundred vehicles included in commercial fleet tests.

(l) The synthetic lubricant did not adversely affect gaskets and fiber timing gears.

Photographs of various engine parts taken during this investigation are shown in Figures 5 to 9.

Oil Inspection Tests

Since the synthetic lubricant is chemically different from petroleum oils, many of the chemical tests applied to petroleum oils do not have the same significance. For example, the values obtained for naphtha insolubles and chloroform solubles on the used lubricant are misleading because of different solubility characteristics of the synthetic oil and its oxidation products. Neutralization number as determined by the conventional ASTM method has a different significance in the case of the synthetic lubricant. The standard neutralization number test on the synthetic lubricant is difficult to run without saponifying the esters formed thus obtaining a value analogous to the ASTM saponification number. In view of the chemical difference between the two lubricants, a more accurate method is to analyze for free as well as total acid and for this determination a modified ASTM method is used in which the results are expressed in milliequivalents per gram of oil.

The measurement of viscosity is as significant with synthetic oil as with petroleum oil because it is a physical property.

The ash value as determined by the ASTM method appears to have the same significance as with petroleum oil since the amount of noncombustible solids in the used lubricant may have a bearing on engine wear and performance. In used synthetic lubricant, ash has been identified as largely lead from the fuel.

It is felt that viscosity, ash value, free acid and total acid are the chemical and physical tests most useful in following the condition of the used lubricant.

Use of LB-550 in Aircraft Engines

Synthetic lubricant LB-550 has been used extensively in aircraft engines by the Army Air Forces and the Air Transport Command. To date, over 150,000 engine hours have been accumulated on this lubricant. Some of the engines operated over 900 hours before overhaul. While the bulk of the oil was consumed in Canada and Alaska, a number of aircraft were flown on the synthetic lubricant in this country during the summer of 1944. The lubricant was directly substituted for petroleum oil in these engines. As a result of this experience, the following conclusions were drawn:

(a) It was always possible in the equipment tested to start engines at ambient air temperatures of –15F without gasoline dilution, and starts have been observed at –30F without dilution.

(b) Freedom from sludge and varnish normally formed by oxidation of petroleum oil in the engines, was clearly demonstrated. This was noticeable, particularly in the piston

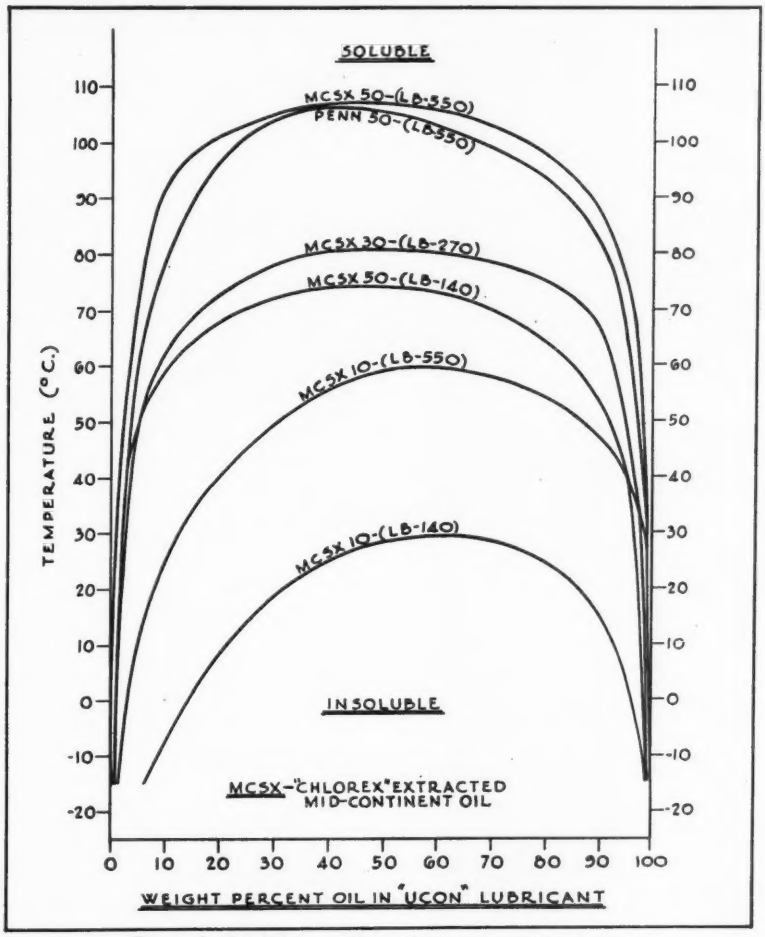


Figure 4. Solubility of "Ucon" Lubricant—Oil Systems.

ring grooves which were always free from sludge deposits.

(c) The oil cooler tubes remained relatively free of sludge accumulations. Furthermore, under extreme low-temperature conditions, congealing of oil in the oil coolers was not experienced.

(d) It was possible to feather propellers that are hydraulically operated by the engine oil at temperatures down to –60F.

(e) The sludge formed was essentially lead compounds from the fuel. These lead compounds, being uncontaminated with oil oxidation products, proved to be denser than the deposits in engines operated on mineral oil, and it is felt that such hard accumulations at certain points in the engine would be undesirable.

(f) Past experience of the ATC has indicated some difficulty with respect to exhaust valve sticking which resulted in engine roughness after 400 to 500 hours of operation of engines. This same difficulty has been encountered with conventional type oils but to a lesser degree based upon the test data. Valve sticking did not occur when valve guide clearances were adequate.

(g) Some increased leakage as compared with petroleum oils was observed.

(h) It was established that engines operated on the synthetic lubricant were much easier to clean up during overhaul than engines operated on petroleum oil. Servicing aircraft was much easier in cold weather and aircraft could be left out-of-doors or uncovered for longer periods during loading and unloading.

Use of LB Series in Small Two-Cycle Engines, Compressed Air Mechanisms, and Compressors

Interesting results have been obtained with various members of the LB series in the lubrication of small two-cycle engines using lubricant-fuel mixtures. The resistance of the synthetics to the formation of sludge, varnish and carbon deposits has proved valuable in this application. The choice of the proper lubricant viscosity depends on the design of the particular engine. The solubility of the lubricant in gasoline, methanol and other fuels is adequate for making the various mixtures used.

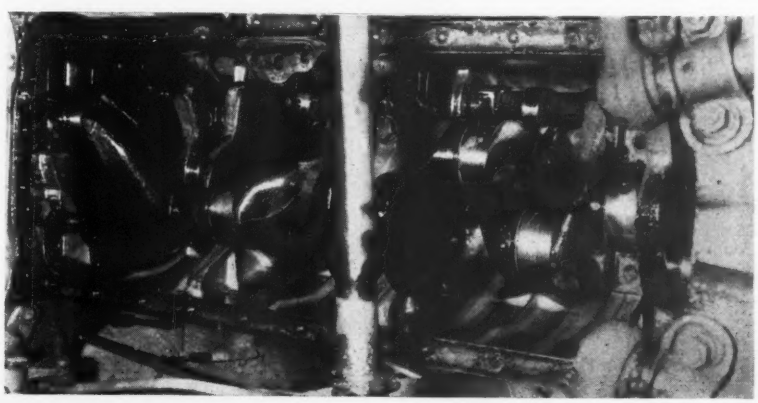
The lubrication of compressed air operated mechanisms such as hammers and drills is being studied. It is expected that the good low-temperature properties, high viscosity indices and resistance to sludge, varnish and carbon formation will prove the synthetics to be advantageous.

Excellent results have been obtained over a period of several months' use of the synthetic lubricants in hydrocarbon gas compressors. Experience with air compressors has so far been limited to low discharge pressures. Interesting results have been reported, and this application is being investigated further.

Other Uses for LB Series

Various other applications of the LB series are being studied. These include leather treating, textiles and textile machinery, calendars and mills for resins and rubber, powder metallurgy and porous metal bear-

Figure 5



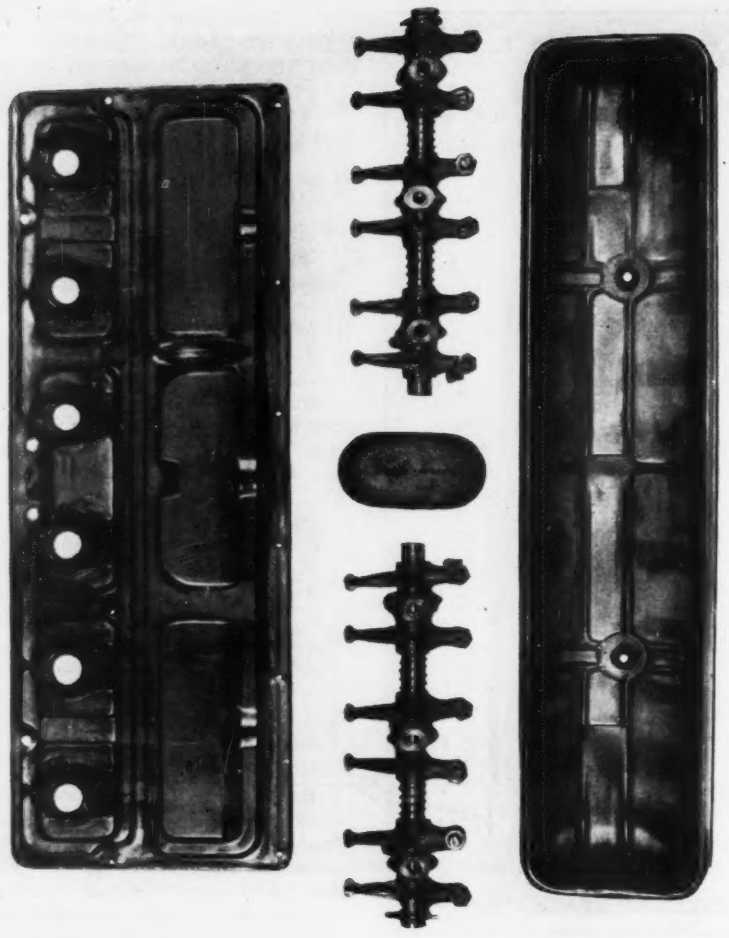


Figure 6

ings, electric motors, refrigerating equipment, transmission and differential lubricants, hydraulic transmissions and torque converters, cosmetic preparations, and plasticizers.

50-HB Series

Physical data for representative products of the 50-HB series are given in Table II. The principal difference between the 50-HB and LB series lies in their water-solubility. As was mentioned previously, the 50-HB series is completely soluble in water at ordinary temperatures, the solubility decreasing as the temperature is raised. The members of the 50-HB series are somewhat hygroscopic, and they depress the freezing point of water to a limited extent. Members of the 50-HB series having viscosities of more than about 100 Saybolt Seconds at 100 F have very little swelling action on natural rubber and are excellent lubricants for both rubber and metal.

The lubricants of the 50-HB series may be used with or without water as a dilutent or coolant. In some applications where water is used with the lubricant and may cause rusting of iron or steel, suitable inhibitors are useful.

The 50-HB series is useful in a great variety of applications where water solubility may be a desirable property. These applications include textile fiber lubrication and conditioning, textile machinery lubrication, paper conditioning, paper and printing machine lubrication, cutting and grinding fluids, wire and metal drawing operations, and other uses.

Hydraulic Applications

The lubricants of both the LB and 50-HB series are useful as hydraulic fluids and as components of such fluids. Applications include hydraulic riveters, aircraft propeller feathering units and other hydraulically operated mechanisms, shock absorbers, and hydraulic brake fluids.

In hydraulic applications such as machine tools where power is transmitted by means of the fluid, the unusual properties of the synthetic

TABLE II—PROPERTIES OF "UCON" BRAND LUBRICANTS—50-HB SERIES

	50-HB-55	50-HB-190	50-HB-260	50-HB-400	50-HB-660	50-HB-2000	50-HB-3520	50-HB-5100
Viscosity Saybolt Seconds								
@ 210F	34.3	54.8	63.5	82.9	123	326	540	744
100F	55.0	190	260	400	660	2000	3520	5100
20F	315	2115	3035	5290	9430	32650	65300	92000
0F	712	6110	9650	16800	30800	112200	212000	276000
—20F	2100	27500	39400	66000	122400	550000	780000	1010000
—40F	7880	151000	229000	370000	733000	.....	.....	.....
Viscosity Centistokes								
@ 210F	2.4	8.7	11.2	16.3	25.7	70.0	116.0	160
100F	8.9	41.0	56.2	86.6	143	433	760	1104
20F	68.6	460	660	1150	2050	7100	14200	20000
0F	155	1330	2100	3650	6700	24400	46200	60000
—20F	458	6000	8600	14400	26700	120000	170000	220000
—40F	1720	33000	50000	80000	160000	.....	.....	.....
V. I. (A.S.T.M. D-567-41)	97	158	153	149	144	133	130	125
Pour Point, F. (A.S.T.M. D-97-39)	—80	—70	—65	—55	—45	—35	—35	—35
Density (g./cc.) @ 210F	.920	.970	.977	.985	.991	.997	.997	.991
100F	.972	1.016	1.023	1.030	1.037	1.042	1.044	1.053
60F	.993	1.034	1.040	1.047	1.053	1.059	1.059	1.059
Min. Flash Point, F. (A.S.T.M. D-92-33)	255	435	435	450	450	450	470	470
Min. Fire Point, F. (A.S.T.M. D-92-33)	280	480	500	500	500	500	500	500

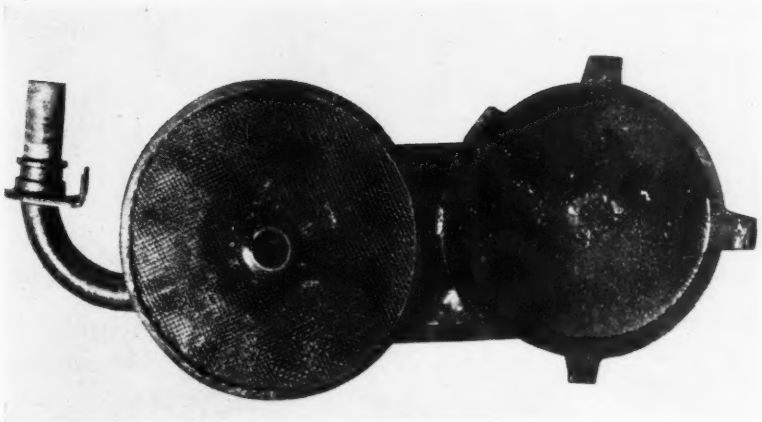


Figure 7

lubricants can be utilized to advantage. In these uses the resistance to sludge and varnish formation and good viscosity-temperature characteristics of the synthetics favor smooth operations and minimum servicing of the equipment. The solvent power of the synthetics for the decomposition products of petroleum oils promotes a cleaning action in systems in which these oils have been used. The LB series is best suited to most applicants of this type.

Shock absorber fluids having desirable operating characteristics are made from these synthetic lubricants. In this service, good viscosity-temperature properties, low pour points and minimum effect on metals, gaskets and rubber seals are important considerations.

The proper formulation of hydraulic brake fluids is important not only from an engineering standpoint, but also from a consideration of public safety. Formulations including the synthetic lubricants and stable solvents have been subjected to extensive tests and are now being widely used.

Metal Drawing, Stamping, and Rolling

The lubricants of both the LB and 50-HB series have found some interesting applications in the forming of various metals. In these applications, the lubricants are used alone or in combination with water or other materials such as palm oil. Various types of wire have been successfully drawn with the lubricants, in some instances resulting in notably bright surface finishes. Rods, bars, sheets and foils have also been successfully drawn and rolled with the lubricants.

In some drawing and rolling applications, it is desirable that the lubricant be easily and cleanly burned from the metal, as in an annealing operation. Tests have indicated that this can be done easily with the synthetic lubricants, the LB series performing somewhat better than the 50-HB series in this respect. In other cases, the water solubility of the 50-HB series is desirable in permitting washing the lubricant from the metal with water. The compatibility of the lubricants with nitrocellulose and other protective coating materials may prove to be an advantage in eliminating a cleaning or degreasing operation before painting, lacquering or enamelling the formed metal.

Heat Transfer Liquids

The resistance of the synthetic lubricants to sludging and varnish formation indicate applications as heat transfer liquids within certain temperature limits. At the present time, insufficient information is available to indicate the maximum temperature at which the lubricants can be used continuously without excessive thermal decomposition, but experimental units have been operated for limited periods at 450 to 475 F without trouble with systems which were completely enclosed except for suitable vents. The 50-HB series appears to be somewhat better suited for this use than the LB series. When using the 50-HB lubricants, the units

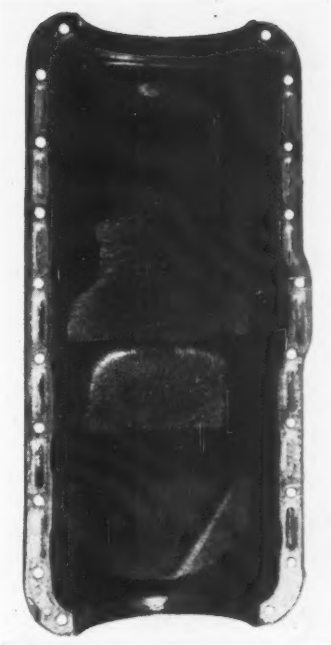


Figure 8

should be designed so that a minimum amount of moisture will be absorbed from the atmosphere during shut-down periods. This is to prevent surging or delays for evaporating the water when the unit is started again. These lubricants offer some interesting possibilities in metal quenching and drawing. Mixtures of water with the 50-HB series provide some particularly intriguing prospects for investigation.

Greases

Interesting greases of the general purpose, low and high temperature types have been prepared from lubricants of the LB series. So far, these greases have been made only in experimental quantities.

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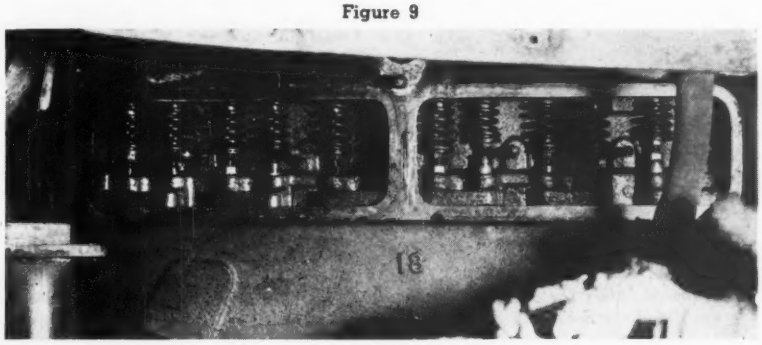
New Synthetic Lubricants: J. C. Kratzer, D. H. Green and D. B. Williams; *Petroleum Refiner, 25,* No. 2 (February, 1946). (This reprint is available without obligation from Carbide and Carbon Chemicals Corporation.)

Figure 9



Silicone Lubricants*

By T. A. KAUPPI AND W. W. PEDERSEN

Dow Corning Corp., Midland, Michigan

* * * * * * * * *

One of the most interesting recent developments in the lubrication field is the use of silicones as lubricants. This paper covers this subject in considerable detail. Since the silicones have relatively flat viscosity-temperature slopes, their use as lubricants where extreme temperature ranges are encountered seems indicated. Results of tests of lubricating properties of these compounds are discussed.

* * * * * * * * *

Silicone Polymers

THE last three or four years have witnessed a remarkable development in the chemistry and general technology of silicone polymers. The first silicone polymer to be made available was a resin which found its principal application as an electrical insulating varnish. At the present time the family of silicone polymers has expanded to include materials as far apart in properties as gasoline is from rubber. In general the silicones can be classified in four groups according to their physical properties.

I. *Varnishes and Resins*

The resinous silicones, when used to insulate electric motors, generators, and other equipment, offer several outstanding advantages because of their stability to heat and resistance to moisture.

(a) Greatly prolonged life of equipment operating under adverse service conditions.

(b) Greater freedom from overload failures, and reduced fire hazards.

(c) Increased horsepower output per unit weight accomplished through redesigning or rewinding with Silicone Insulation.

Silicone resins are also used in formulating protective coatings highly resistant to heat, excessive moisture, oxidation, and ultra-violet rays. Silicone based paints and enamels which withstand temperatures up to 500 F are used for coating ovens, smokestacks and exhaust equipment of internal combustion engines.

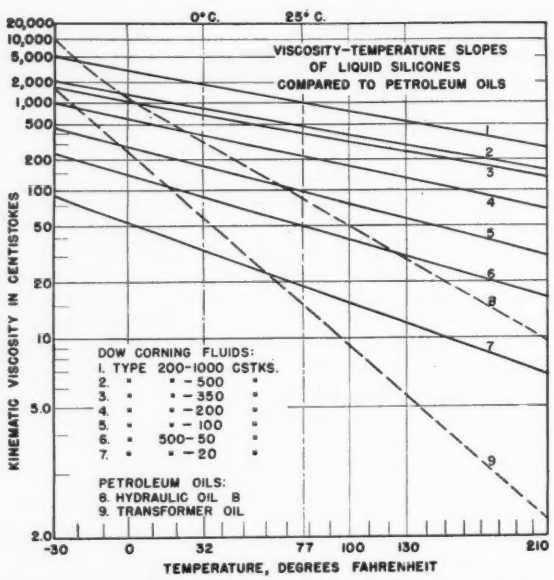


Figure 1. Viscosity-temperature slopes of two types of silicone fluids and two types of petroleum oils.

II. *Silicone Rubbers*

This is a group of rubbery organo-silicon oxide polymers characterized by exceptional heat resistance and retention of flexibility at temperature as low as –70 F. Silicone rubbers can be obtained in molded or extruded shapes, and are also used to coat glass fabrics for high temperature gasket and diaphragm applications.

III. *Grease and Compounds*

Silicone electrical compounds, grease-like materials which change very little in consistency over the temperature range of –40 F to 400 F, have been used widely as auxiliary dielectric materials in ignition systems of aircraft and in disconnect junctions of radio systems. Other silicone greases have been developed for high and low temperature lubrication uses, and these will be discussed in more detail later.

IV. *Silicone Fluids*

This is a group of liquid polymers obtainable in a very wide viscosity range and including volatile fluids as well as nonvolatile oils. The silicone fluids are heat

**Presented before the March 15, 1946, meeting of the New York Section of the A.S.L.E.*

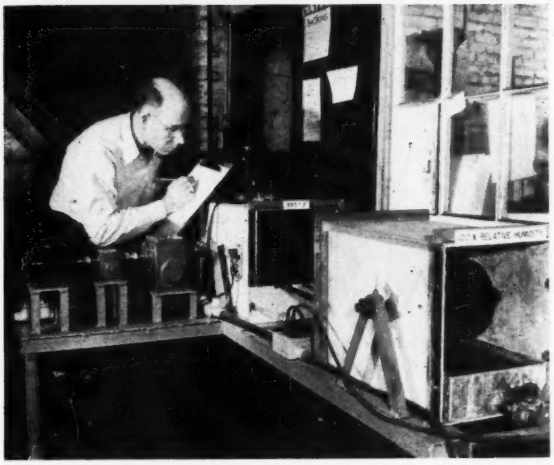


Figure 2. Apparatus designed to test the lubrication life of a silicone fluid (DC 710 R) and petroleum oils on chains cycled through a temperature chamber held at 350F. and a humidity chamber with rest periods at room temperature intervening.

stable, inert, have good electrical properties and are insoluble in water.

The purpose of this paper is to discuss the relationship of the general properties of silicone fluids to lubrication applications, and to describe some of the experience to date with the lubricating behavior of silicone greases.

General Properties of Silicone Fluids

Silicone fluids possess a combination of properties which go a long way toward eliminating some of the problems encountered by the lubrication engineer. Thinning out at high temperatures and the corollary thickening at low temperatures are effects which are greatly minimized in the silicone fluids. Fig. 1 compares the viscosity-temperature slopes of a family of silicone fluids with some typical petroleum oils, and the difference is quite apparent. For instance, if a silicone fluid and a petroleum oil of high viscosity index both have a viscosity of 50 centistokes at 100 F, then at 0 F the petroleum oil will have six times the viscosity of the silicone fluid.

Many lubrication problems involve a rather delicate balance between obtaining an oil with low enough viscosity and one with sufficiently low volatility. In other words, a kerosene with no tendency to evaporate would be very useful in some applications. Silicone fluids do not quite meet this specification, but it is possible to obtain non-volatile silicone fluids in the viscosity range of 3 to 10 centistokes.

Low temperatures such as are encountered in aircraft applications often force a compromise between pour point and volatility or between pour point and viscosity. That is, a petroleum oil of low enough volatility and high enough viscosity for a given application may have much too high a pour point. The DC 200 silicone fluids, which are non-volatile and which can be obtained at viscosities of 1000 centistokes and higher, all have pour points below –50 F.

The utility of properties such as heat stability, non-volatility and oxidation resistance is illustrated in Figs. 2 and 3. Fig. 2 shows an apparatus designed to subject a conveyor chain to alternate high temperature (350 F.) and high humidity, with a rest period between these two extreme conditions. The purpose of this test machine was to develop lubricants which would withstand this type of operation, and Fig. 3 shows one of the test results. After six weeks of operation, the length of chain lubricated with petroleum oil has rusted so badly that the rollers will no longer turn, largely because the high temperature condition has oxidized and evaporated the petroleum oil. The chain treated with silicone fluid (DC 710 R) is still in excellent condition. After 21 weeks it shows very little rusting and still has a protective film of the silicone lubricant.

Lubricating Properties of Silicone Fluids

One of the first experiments carried out on the lubricating properties of silicone fluids involved pumping the fluid with a small gear pump at various outlet pressures. The pump was operated at approximately normal rated speed. An initial test on an SAE 10-motor oil showed that no appreciable wear occurred during 10 days of operation at outlet pressures ranging up to 100 psi. A run made with DC 200 silicone fluid of comparable viscosity produced extreme wear, as shown by suspended particles of steel in the fluid, within one hour of operation at 25 psi outlet pressure. When the pump was disassembled, it was found that the wear had occurred mostly in the steel bushings supporting the gears, and between the gears and the steel side-plates; apparently very little wear had occurred between the gears themselves. Several of these gear pumps, of various sizes, were being used regularly in the manufacture and processing of silicone fluids, and it was found that no trouble with wear had been encountered. However, the pumps were operated at considerably lower than normal rated speeds, and the outlet pressures rarely exceeded 100 psi.

It was apparent from the above and from similar experiences in other types of equipment that the DC 200 fluids did not have the lubricating properties of an ordinary petroleum oil. DC 200 fluids of various viscosities were being used at that time for instrument lubrication with considerable success, but whenever they were tested in applications involving high rubbing speeds or high unit bearing pressures, the results were unfavorable. The conclusion was reached that the DC 200 type of silicone fluid has no extreme pressure lubricating properties, and actually begins to fail at unit pressures considerably lower than those normally accepted as the beginning of the extreme pressure range.

Figure 3. After 6 weeks of testing in the apparatus shown in Figure 2 the upper length of chain lubricated with a petroleum oil was badly rusted and the rollers were frozen. The lower length of chain lubricated with DC 710 R is still in excellent condition after 21 weeks of testing.

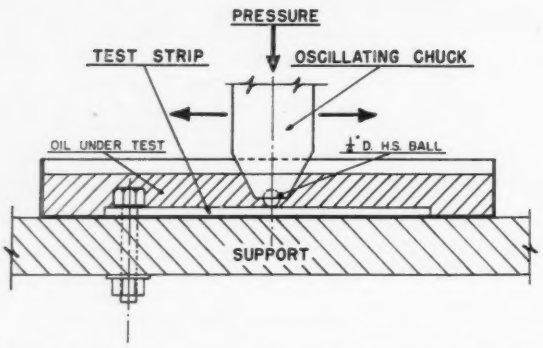


Figure 4. Lubricant testing device for measuring wear between sliding surfaces over a range of rather low pressures.

Wear Test

A few trials on the available lubricant testing machines showed that they were not designated to measure lubricating properties in the pressure range in which DC 200 began to fail. Therefore, a simple device was set up to permit measurement of wear between sliding surfaces over a range of rather low pressures. As shown diagrammatically in Fig. 4, this lubrication tester merely slides a ¼ inch metal ball over a flat metal strip. The ball is held rigidly in a chuck which can be vertically loaded in the range of 500 grams to 4000 grams, and which has a horizontal reciprocating motion. The amplitude of the oscillation is 2⅜ inches, and the speed is 72 complete oscillations per minute. The flat metal strip is held stationary in a pan which contains the oil to be tested, and the usual method of evaluation is to weigh the test strip before and after a 2-hour run. The loss in weight of the test strip, or in some cases the depth of the groove worn in the strip, is the measure of lubrication efficiency.

A few preliminary runs were made on the wear tester to determine reproducibility of results and the effects of varying loads on the amount of wear. Fig. 5 shows the results obtained when a steel ball bearing was used in the chuck and a strip of shim brass was the wearing surface. The tester was operated for two hours

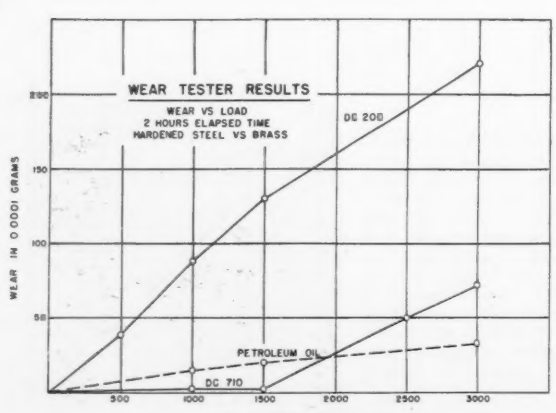


Figure 5. Wear in terms of weight lost by a brass strip against which a hardened steel ball lubricated with an SAE 10 petroleum oil and two silicone fluids is rubbed at a constant rate under various loads.

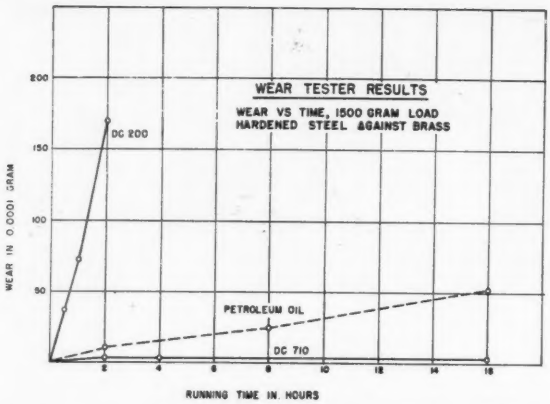


Figure 6. Wear in terms of weight lost by a brass strip against which a hardened steel ball lubricated with an SAE 10 petroleum oil and two silicone fluids is rubbed at a constant rate and under a constant load for various periods of time.

and the weight loss of the brass strip plotted against the load applied to the steel ball. It is apparent that the wear obtained with DC 200 silicone fluid is greater than with an SAE 10 motor oil. Similarly, Fig. 6 shows the effect of running time of the tester on weight loss of the brass strip. The wear obtained with the petroleum oil in 16 hours is about the same as that obtained with DC 200 in ¾ hour.

Since the results were reproducible and explained why difficulties had been encountered in the use of DC 200 fluids, the wear tester was used to evaluate the lubricating properties of a large number of experimental silicone fluids. It was found that variations in the chemical composition of the silicone fluids had a great effect on lubricating properties, and several new types of fluids were developed.

The wear test results on one of the newer silicone fluids are also shown in Figs. 5 and 6. DC 710, in Fig. 5, shows less wear up to 2000 grams load than SAE 10 petroleum oil, but about twice as much wear at 3000 grams load. Fig. 6 shows that at 1500 grams load, DC 710 produces considerably less wear than the petroleum oil at all running times up to 16 hours. The tentative conclusion to be drawn from these results is that DC 710 is better than petroleum oil for steel-to-brass lubrication at moderate loads, but is less effective than petroleum oil at loads approaching the extreme-pressure range.

Wear on Various Metals

Table No. 1 shows the results obtained when a hardened steel ball slides on various metal surfaces. It is apparent that aluminum has the greatest tendency to wear under these conditions, and spring steel the least. DC 710 is a definite improvement over DC 200, and appears equivalent to SAE 20 except in the case of aluminum. It should be noted that test values below 5 are all equivalent, since this is the order of accuracy of the test procedure.

It is interesting to note the relative behavior of DC 200 with soft steel and spring steel, and to compare this with results obtained on the pumping test. The gear pump cited previously had soft steel sleeve bearings supporting the gears, and soft steel side plates, and excessive wear occurred on these parts. Almost no wear

TABLE I—WEAR TESTS ON METAL COMBINATIONS, WEAR EXPRESSED IN 0.001 GRAMS, 2-HOUR TEST 1500 GRAMS LOAD

Hardened Steel Ball against	Lubricant SAE 20	DC 200	DC 550	DC 710
Brass	4	130	40	3
Aluminum	65	250	430	300
Magnesium	10	40	45	4
Soft Steel	0	750	330	0
Hardened Spring Steel	2	4	3	3

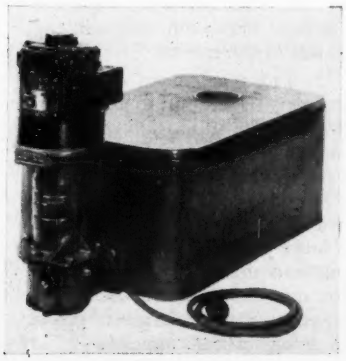
was found on the gears themselves. Another test, using a rotary vane-type pump, has been operating with DC 200 with excellent results. In this case, the steel parts are hardened, and the side plates are of bronze.

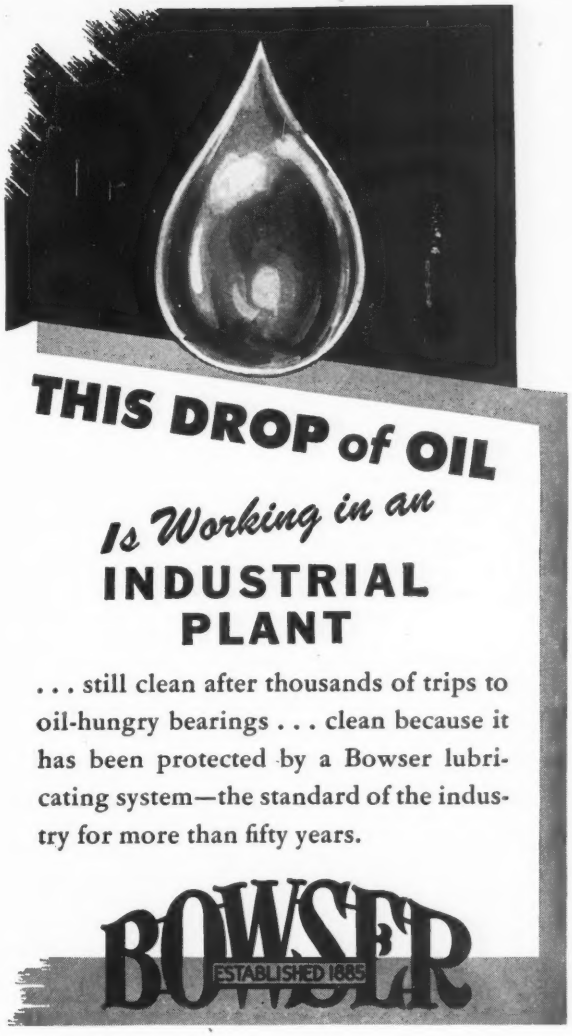
The data discussed above show that considerable differences in lubricating ability exist between the various silicone fluids, and that at least some of them are suitable for a range of lubrication applications. Even the DC 710 fluid, however, is not an extreme-pressure lubricant. Since silicone fluids are totally different from petroleum oils, it is almost impossible to predict from petroleum oil experience how a particular metal combination will behave with silicones. In general, preliminary tests will quickly show whether one of the silicone fluids is suitable from the standpoint of preventing wear.

The concluding part of this paper, dealing with silicone lubricating greases and bearing lubricants, as well as a discussion of the paper by C. R. Gillette of the New Departure Division of General Motors Corporation, will appear in the next issue of LUBRICATION ENGINEERING.

Coolant Pump and Tank

The Delta Manufacturing Company, 600 East Vienna Ave., Milwaukee 1, Wisconsin, announces a coolant pump and tank assembly, said to be suitable for many machines where a free flow of coolant is required. The pump, which is available separately, is highly adaptable because the flat machined flange permits its use on most wet machine tools. The manufacturer states that the pump has a capacity up to 30 gpm at low heads and that it will deliver water up to 2 gpm to a 14 foot head. The motor is ¼ hp, fully enclosed and has double-sealed ball bearings, lubricated for life. The tank has a capacity of 16 gallons and is equipped with a settling basin and wire mesh filter screen to keep the coolant free from chips. The price is claimed to be exceptionally reasonable.

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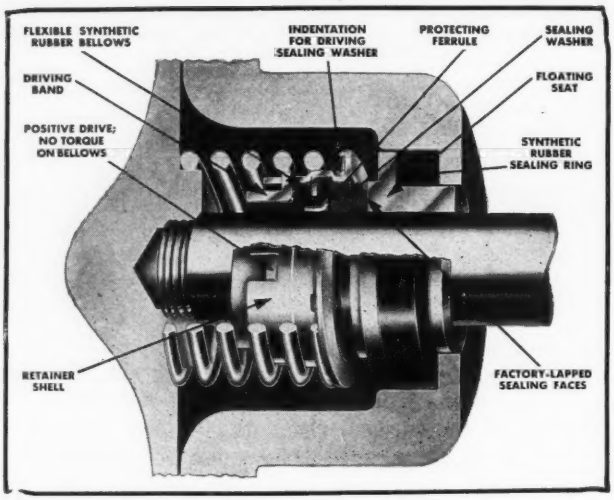
Mechanical Seals*

By CARL E. SCHMITZ

Chief Engineer, Crane Packing Company



This paper deals with the problems encountered in packing or sealing rotating shafts. Many factors are involved in addition to size and speed of the shaft. Operating conditions such as temperature, pressure, nature of material being sealed, space requirements, and of course lubrication of the rubbing surfaces of the seal, all have to be taken into consideration in the design of mechanical seals. The author states that the mechanical type of seal is supplanting the packing gland in an ever increasing number of applications.

THE problem of packing or sealing rotating shafts has a long, interesting history and there is perhaps no field of endeavor in which so much time can be spent experimentally in the field and in the laboratory. To make it the more complicated and interesting is the fact that up until rather recently, shaft speeds of from 1200 to 1800 rpm and a little later 3600 rpm were considered tops insofar as speed was concerned. At the present time design engineers are talking shaft speeds of 20,000 rpm in many contemplated designs — the advent of the higher electric cycle motor has made it possible to run shafts at these high speeds; and the savings that can be accomplished, weight and spacewise, impose the necessity to cope with such problems. The trend today is toward lighter, more compact equipment, having consistently higher efficiencies. This has been largely an outgrowth of demands of the aviation industry, and now is being extended to industry in general.

In the field of pressure ranges, pressures of 300 psi to 400 psi were considered high. Today designs call for equipment to operate at pressures far above these figures and in some instances pressures of several thousand pounds are being discussed rather freely.

The problem of packing and sealing offered many difficulties at the lower speeds and pressures, and a great deal of necessary experimental work had not been concluded at these lower pressures and speeds when there was imposed upon the picture by the needs of the design and process engineer these radical new departures to higher speeds and pressures. Packing can be designed to give relatively satisfactory life and good engineering practice is followed provided lubrication can leak along the shaft or rotating members through the stuffing box and thus serve to lubricate the packing itself as well as the point at which the shaft contacts the packing. The resultant leakage, in some instances, was and is still permissible.

In the early days the refrigeration industry perhaps imposed the most difficult problem in that the oil in the system became saturated with the refrigerant and was lost along with the oil at the end of the stuffing box. This presented several problems:

1. The loss of lubricating oil necessary to keep the system in good repair.

2. The loss of the refrigerating medium absorbed in the oil.

If the oil loss was bad this would be sufficient to seriously impair the efficiency of the whole unit. So as might be expected, the early pioneer work of providing a mechanical means of sealing rotating shafts was done in the refrigerating engineering field and seals on refrigerating compressors have been outstandingly successful.

3. Efficient refrigerating mediums are frequently toxic and irritating to human beings and thus there is greater necessity for complete sealing against loss or leakage into the adjacent space.

4. Mechanical seals have effectively eliminated the necessity for frequent adjustment of glands. This has often been the cause of many difficulties in the hands of the novice.

5. The mechanical seal, having narrow friction faces, makes possible full utilization of power input for the purpose intended. Frequently packing glands with conventional packing were drawn up so tight as to consume a large portion of the power input and thus made it necessary for manufacturers to use larger power units for a given result in refrigerating capacity.

* *Presented at the January 25, 1946 meeting of the Chicago Section of A.S.L.E.*

There are several manufacturers who build seals that are acceptable for such service. There are some which naturally possess superior qualities to others. The most commonly accepted units utilize a seat or stationary member of cast iron, Meehanite or some other type of cast iron. Various types of carbon, of either the sintered, filled type, or the type bonded by synthetic resins of various kinds are successfully used for washers or revolving units. Since in the majority of instances refrigerating compressors operate at speeds from 300 to 1200 rpm the speed conditions are not hard to cope with. Further, since refrigerating compressors require a liberal circulation of oil, means are provided for adequate lubrication and cooling of the seal rubbing faces.

Rather recently some radically new designs have been contemplated. I have discussed with refrigeration engineers designs on compressors where contemplated speeds run up to as high as 18,000 rpm. In supplying seals for these compressors, new problems will be imposed on seal designers and engineers in that higher temperatures, greater rubbing speeds and the problem of lubrication will be the more difficult. Fortunately the pressures encountered in the refrigeration field to date have not been unreasonably high. The maximum is somewhere in the neighborhood of possibly 200 psi with the more general high of 150 psi being experienced. This top pressure range is experienced most generally at the time when the compressor is idle.

The problem of sealing is minimized while the shaft is rotating since at that time the oil film is constantly in motion. While precision work is always necessary when dealing with seals, it is of special importance that proper lapping be supplied so as to assure a liquid and gas tight joint when standing idle. Certain necessary components of a good refrigeration system lubricant are particularly hard on synthetic members and tend to cause excessive swelling and weakening of such synthetic sections.

New synthetics and constant work on the problem are leading to a successful solution of that problem. The ability of the lubrication used to provide an effective film between the seal faces is important and most refrigeration system lubricants meet that problem to the satisfaction of all concerned.

A good mechanical seal must provide means of compensating for some axial movement. It must also possess sufficient flexibility to compensate for some radial movement caused by bearing wear, shaft flexing, and general mechanical deficiencies encountered in such equipment. Further flexibility must be embodied so that as wear occurs at the seal faces it can be compensated for without distortion or imposition of stresses or strains on any of the parts and to provide against the faces wearing apart, which might cause loss of both the lubricant and the refrigerating medium.

A good mechanical seal must be so constructed that the torque load is not imposed upon the flexing member regardless of the material used in its construction.

Considering the rotating shaft in a journal or bearing, there is always a rolling action and it is reasonable to assume that if sufficient quantities of oil are available the shaft will tend to roll the lubricant under it so as to separate and avoid metallic contact between the shaft and the bearing or journal. The movement and lubrication of the stationary and rotating faces of a seal are relatively different. In the first instance, two perfectly lapped faces, the surfaces of each being approximately within 1½ light bands of flatness, are held in intimate contact by springs or other methods of preloading and thus impose upon the lubricant the necessity for providing a film between the two faces so as to effectively separate them in such a manner as to minimize both friction and wear.

This calls for a lubricant with a viscosity sufficiently low so that it may move between the two faces and yet have sufficient body to withstand the frictional load, as well as the pressure of the system and spring load that are necessary to maintain good sealing characteristics so as to hold both oil and refrigerant leakage to the absolute minimum.

There are today a few compressors being manufactured so designed as to use conventional packing, but these are rapidly disappearing from the field and as the matter stands at the present time practically 100% of the small household type refrigerating units are supplied with some kind of mechanical seal. The large units running up into hundreds of tons capacity are rapidly converting to the mechanical seal since as mechanical seals stand at the present time they have overcome the hazards and costly maintenance previously experienced with packings.

To provide a little further insight into the picture of the mechanical seal as it is generally applied today to the mechanical field, I want to discuss for a few moments some other devices in which seals are being used to great advantage.

A good example of what can be expected in the use of seals is the automobile water coolant pump. Up until relatively a few years ago almost all automobile water pumps were packed in some conventional manner and a method was provided for repacking and adjusting the tension on the packing while in service. Today, with possibly one or two exceptions, every major automotive engine manufacturer is using some type of mechanical seal, thus entirely eliminating the necessity for adjustment, repacking, and bothersome maintenance. Likewise, the hazard of losing the coolant has been eliminated and much has been added to the comfort of the automobile owner, freeing him entirely from loss and worry. Many of you no doubt remember the old method, and have frequently looked for the proper tool to adjust a leaking water pump gland. Thanks to the mechanical seal, the water pump now is good for the life of the car. Here the problem is relatively a simple one since pressures are almost always low, never exceeding 10 psi, so the problem is minimized in so far as pressure is concerned.

It is true that automotive water pumps usually operate at relatively high speeds — approximately 4000 rpm being the average cruising pump speed. The problem insofar as cooling and lubricating is concerned, resolved itself into practically three major categories:

1. Water.
2. Alcohol-type commercial anti-freeze mixtures.
3. Ethylene-glycol type coolants.

Relatively safe operating temperatures are most generally encountered since if the temperature runs over 170 F there is always danger of boiling, particularly in the case of alcohol-type coolants. Water could reach 212 F and ethylene-glycol a somewhat higher temperature. However, higher temperatures are encountered only when there is some radical difficulty with the coolant system generally. Thus, this particular industry has solved a vexatious problem by utilization of the mechanical seal.

Seals are also used on aviation coolant pumps and most industrial and commercial engines of various types and kinds requiring coolant

systems. Shortly before the advent of World War No. 2 there was a definite demand by manufacturers of pumps and other industrial appliances to provide a more efficient means of sealing rotating shafts than was afforded by conventional packing. With this in mind a wide range of seals have been developed for practically every type of industrial application, including seals for successfully handling gasoline, lubricating oil, water and other of the more simple materials which present no particular problem insofar as corrosion, lubrication, or cooling is concerned.

If we only had these relatively simple materials to contend with we could rather rest on our laurels in the way of accomplishments already achieved. But because of many new developments in the field of science, the chemical and processing engineer is calling for seals for use on the very lightest of hydrocarbons such as propane and butane as well as seals for handling blown vegetable oils, tars, and asphalts. One can realize at a glance how difficult and varied the problem becomes. It is necessary to select the proper materials for the seat and washer. Sometimes both are of some type of metal designed to run together with a minimum of lubrication and cooling at high speeds and there is always the important requirement—"There must be no leakage, or practically none."

It has been our experience that insofar as the lighter liquids are concerned they present a most difficult problem because of their lack of lubricating qualities and lack of ability to keep the seal faces apart sufficiently to avoid contact. The heavier, more viscous materials present the problem of moving between the seal faces, thus forcing them apart to the extent that there is some leakage. Some of these difficulties are worked out from the standpoint of the proper seat and washer materials which experience shows have relatively good qualities insofar as running together in almost intimate contact with a minimum of friction. The matter of relative hardness of the stationary seat and revolving washer play an important part in the selection of materials although we have found from experience that there are no materials that will operate in intimate contact with one another dry. Some film must be provided between them.

Sometimes it becomes necessary to use the double seal construction and to circulate lubrication between the seals. This construction requires additional equipment to handle the circulation of the seal oil and is not generally too popular.

Further, we find that if an attempt is made to operate intimately lapped parts together dry, temperatures jump to destructive heights in a matter of relatively few seconds and thus it becomes necessary to have sufficient fluid in the seal chamber to carry away the excessive heat generated. In some instances we are called upon to supply equipment to meet conditions where space limitations are such as to make it extremely difficult to make adaptations. However, of late engineers are becoming more confident of the ability of the mechanical seal to solve the problem and thus are inclined to change designs so as to accommodate the installation of the seal insofar as space is concerned.

Standard mechanical seal construction permits use up to 200 psi. When pressures above that are encountered balancing is necessary. Much important work along this line has already been accomplished. The problem of shaft sizes is important. Shafting is used in 1/16″ increments, and we start at ¼″ and have designed seals for shaft sizes up to 7″; in the lower range up to 3″ in 1/16″ increments, 3⅛″ to 5″ in ⅛″ increments, and above that in ¼″ increments. This will give you some idea of the large expenditure that must be made for tooling. We have made some designs for 36″ seals. These larger seals are in themselves a machine requiring the same precision employed in the smaller sizes.

Seals are already in use on the pumps of transcontinental pipe lines —here you can appreciate the high speeds and pressures encountered. The seals for this job constitute a most complex problem, but solution is necessary to assure high operating efficiency.

Another problem of interest is the use of seals for handling black sulphite liquor—a miserable problem that had to be solved for the pulp and paper industry. The installation involved the most severe problem of corrosion and abrasion. It was solved and today mechanical seals are giving satisfactory service in one of the world's largest mills. The use of seals is saving hundreds of dollars in maintenance and loss of time costs.

We have experimented with and used many innovations in the way of metals and other materials for seat and washer construction. Many grades of ferrous castings—close-grained cast iron, phosphorized cast iron, boronized cast iron, Meehanite, Gunite, and Niresist are only a few in this category. Nitralloy, various grades of cemented carbides and lately nitrided 18-8 stainless steels have been found to have merit under certain operating conditions. Graphmo, 52-100, and high-speed tool steels also find a use among the many materials that find a place in the mechanical seal field. Many bronze alloys have been tried in field and laboratory tests and any new material publicized is immediately tried to ascertain whether or not it can be used to solve a problem. The glass and ceramic industry have contributed and some installations require such materials for successful performance.

The magnitude and ramifications of the industry cannot be fully appreciated unless one is engaged in it. As previously stated, perhaps no field of endeavor presents more problems, and especially over such a wide field.

You can perhaps now better appreciate why this industry can and is utilizing the endeavors of practically every type of technician. We are moving forward trying to keep pace with many new developments in practically every field of industrial and scientific development. Every day brings a new problem. Today a problem is solved—tomorrow another—and so we move on.

Definite progress is being made. It must be pointed out that the seal manufacturer is pioneering a field in which there is little in the way of available literature to which the seal engineer may refer for help or guidance. All of the advances made are closely guarded by the manufacturers making them and thus you can see how difficult it is to make substantial progressive headway without vast expenditures of time and money.

Research and design are expensive, when directed to a relatively new field of endeavor. Proper personnel is difficult to obtain. Today we can and are supplying seals for work that a few years ago was considered impossible.

No doubt the mechanical seal will, at some day in the future, reach the point when information concerning what to use for this or that material may be a matter of referring to some convenient handbook which will have in it at least a nucleus of information sufficient to guide us along the proper paths. This may be wishful thinking on my

part, but it seems as though such an important development must, at some time, warrant public information, at least in brief form which can be available to the public and the interested engineers.

Now, insofar as the lubrication engineer is concerned, the mechanical seal is of special interest to him for several reasons—those most apparent being:

1. The necessity for keeping a liberal supply of lubrication available at the point at which it is required to provide a maximum in lubricating efficiency.
2. The necessity for avoiding waste of the lubricant itself.
3. Exclusion of dirt, dust and grit which will, in time, so contaminate the lubricant as to render it absolutely worthless.
4. To reduce to the minimum lubrication leakage and thus keep maintenance costs down.

If we are to keep pace with the new high-speed requirements of the mechanical engineer, we must provide liberal lubrication at all times. We cannot possibly countenance the possibility of lubrication running low and thus damaging valuable equipment, to say nothing of the cost of replacement and loss of time. This holds equally true for the conventional solid bearing as well as for anti-friction bearings. When glands are mechanically sealed oil can be recirculated and cooled if occasion warrants.

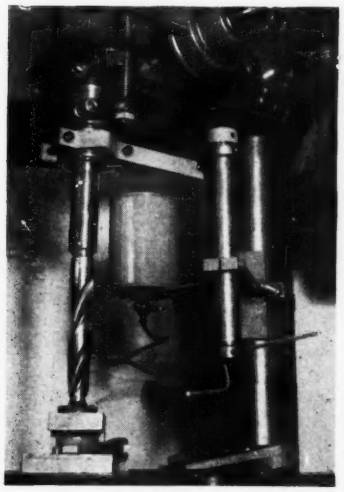
Maintenance engineers in some industries report management insisting on cutting lubricating costs. The properly designed mechanical seal permits practically negligible oil loss. In many instances the cost of initially installing seals is covered by savings in lost oil. Now that might not be too important to the firm or individual selling the oil, but I think we can agree that perhaps no industry has tried more diligently to give the customer more service for his money.

Nothing is more destructive to the value of a good lubricant than dust, dirt, or foreign inclusions. The mechanical seal which holds all of the oil in the system likewise excludes all foreign substance from entering the system, thus prolonging the useful service that good lubrication gives.

It has been found necessary to construct seals to take care of work that necessitates elimination of liquid in the seal cavity for short lengths of time and to take care of jobs that involve the handling of liquids contaminated by dirt and foreign matter. We have developed a seal so constructed as to provide an outside source of lubrication to the seal faces. Here the lubrication engineer will be called upon to supply the proper lubricant for a wide variety of conditions.

The mechanical seal is here to stay. Time will show improvement because we in the industry will not go backward, but we do need the experience and knowledge of engineers in other fields. The lubrication engineer can and will be of great help.

Brush for Lubricating Drill Presses and Punches



The Charles L. Jarvis Company of Middletown, Conn., has announced the *Lubro-Brush,* a fully automatic device said to be suitable for lubricating and cleaning taps, drills or reamers if mounted on drill presses and for cleaning and lubricating punches. It is claimed that this device can be installed in a few minutes on a standard drill press or similar device. Its principal attraction is a simple cam action which transmits a short lift stroke into the sweeping action of the brush. The brush while in rest position receives a few drops of oil while the tap or drill is engaged and working.

New Coolant

Kisch Associates, 75 N. Willow Street, Montclair, New Jersey, have announced a new coolant and cutting fluid called *Kasso.* It is claimed to have unusual cooling properties, in addition to being rust inhibited and non-irritating. The manufacturer states that there is no separation if frozen and that no smoke or vapor is formed in its use. When diluted according to instructions it is recommended for a wide variety of applications including machining of plastics such as polystyrene and methacrylate.

COOLANT AND CUTTING OIL STRAINERS

STRAINER PRODUCTS CORPORATION

75 NORTH WILLOW STREET

MONTCLAIR, NEW JERSEY

Measurement of Lubricant Film Strength In the Region of Boundary Friction*

PART II

By VICTOR A. RYAN

Director of Research for The Crown Cork and Seal Co., Baltimore, Md.

Practical Application of Transition Tests

The practical value of any test method depends upon its ability to indicate the probable performance of a material under actual service conditions. In the case of boundary and extreme pressure lubricants, it is felt that the joint use of the one-minute transition load and the three-minute transition pressure tests can be used to advantage in this respect. A short description will illustrate the manner in which these tests were used in the solution of a rather difficult lubricating problem.

The problem assigned was that of securing or producing a lubricant for a newly invented machine designed for splash oiling. The parts to be lubricated comprised several heavy cam and roller closing mechanisms operating at extreme pressures, dies for stamping and drawing metal, and very thin slides for moving the drawn stock. The lubricant had to function as an extreme pressure lubricant to prevent seizure between cams and rollers, as a drawing oil to prevent scuffing on the drawn stock and the dies, and as a light viscosity lubricant to oil the thin slides.

After numerous unsuccessful trials of proprietary lubricants of high load carrying capacity and after much redressing of scuffed parts, the laboratory succeeded in formulating a lubricant which gave satisfactory performance from the start. It was comprised of 7 parts of raw sperm oil and 1 part of sulfurized sperm oil. After 18 months of continuous service, the price became prohibitive and it was necessary to develop an alternate.

A series of oils was compounded having the properties shown in table 1.

TABLE 1—Principal Properties of Test Samples

Sample No.	Per Cent Non-Saponifiable	Neutral Fat	Free Fatty Acid (Oleic)	Sulphur	Met-Org Ester	Viscosity S.U.S. 100° Fahr.
1	0.60	93.49	3.91	1.00	1.00	220.4
2	25.45	69.64	2.91	1.00	1.00	193.0
3	50.30	45.79	1.91	1.00	1.00	169.6
4	75.15	21.94	0.91	1.00	1.00	148.5
5	86.58	10.97	0.45	1.00	1.00	140.7
Raw+Sulf Sperm	43.20	50.44	4.86	1.50	0.00	139.4
6	50.30	46.26	1.94	0.50	1.00	166.2
7	50.30	46.50	1.95	0.25	1.00	164.0
8	50.29	46.75	1.96	0.00	1.00	162.0

* *Presented at the First Spring Meeting of the American Society of Lubrication Engineers, Chicago, Illinois, April 5 and 6, 1946.*

The first part of the series consisted of samples 1 to 5, inclusive, in which the sulfur and metallo-organic ester additives were kept constant, while the ratio of non-saponifiable to neutral fat was varied. Consequently, any differences in test results would be due to the ratio of mineral to fatty oil.

The one-minute step test was run in comparison with the standard sperm oil mixture in an effort to rate the samples in the order of transition load. The results are listed in tables 2 and 4 and are shown graphically in figures 2 and 5. Reference to figure 2 shows that samples 1, 2, and 3 have the same transition load and,

TABLE 2—One Minute Transition Load Step-up Tests on Samples 1, 2, and 3

Applied Load In Pounds	Sample Number 1 Torque	1 Wear (Teeth)	2 Torque	2 Wear (Teeth)	3 Torque	3 Wear (Teeth)
500	12	0	13	0	14	0
750	15	2	15	2	16	2
1000	16	3	17	3	18	3
1250	18	3	19	4	21	3
1500	20	4	21	4	23	4
1750	21	4	22	4	25	4
2000	22	10	24	8	27	8
2250	24	22	25	14	29	9
2500	25	15	26	15	30	16
2750	25	18	27	17	31	37
3000	27	22	29	17	32	38
3250	28	32	31	22	35	49
3500	31	45	33	31	37	50
3750	34-110	Failed	35	50	38-100	Failed
4000			37-110	Failed		

(These data are shown graphically in figures 1 and 2)

TABLE 3—Three Minute Transition Pressure Step-up Tests on Samples 1, 2, and 3

Applied Load In Pounds	Sample Number 1 Scar Area*	1 Psi Pressure	2 Scar Area	2 Psi Pressure	3 Scar Area	3 Psi Pressure
750	.00864	86800	.00806	93000	.00931	80500
1000	.....	.....	.....	.....	.....	.....
1250	.....	.....	.....	.....	.....	.....
1500	.00960	156300	.01056	141100	.01036	144800
1750	.00960	182300	.01084	161400	.01162	150800
2000	.01436	139300	.01624	123400	.01651	121200
2250	.....	.....	.....	.....	.....	.....
2500	.01632	153200	.01718	145500	.01960	127500

* *Scar Area = 2 (0.48 w)*

(These data are shown graphically in figure 3)

TABLE 4—ONE MINUTE TRANSITION LOAD STEP-UP TESTS ON SAMPLES 4, 5, AND RAW+SULF. SPERM

Applied Load In Pounds	Sample Number 4 Torque	4 Wear (Teeth)	5 Torque	5 Wear (Teeth)	Raw+Sulf. Sperm Torque	Raw+Sulf. Sperm Wear (Teeth)
500	15	0	15	0	14	0
750	19	1	18	2	17	2
1000	21	4	21	2	19	3
1250	24	5	24	3	20	3
1500	26	9	25	4	21	4
1750	27	12	27	9	22	4
2000	28	15	29	12	22	4
2250	30	18	31	13	23	15
2500	35	20	33	15	25	16
2750	33	23	34	16	27	14
3000	35	26	36	20	29	18
3250	36	39	37	35	31	18
3500	38	43	38	43	32	20
3750	38-110	Failed	38-120	Failed	38	19
4000					39	22
4250					42	26
4500					44	26
					OK at end of 5 min.	

(These data are shown graphically in figures 4 and 5)

TABLE 5—THREE MINUTE TRANSITION PRESSURE STEP-UP TESTS ON SAMPLES 4, 5, AND RAW+SULF. SPERM

Applied Load In Pounds	Sample Number 4 Scar Area	4 Psi Pressure	5 Scar Area	5 Psi Pressure	Raw+Suf. Sperm Scar Area	Raw+Suf. Sperm Psi Pressure
750	.00792	94700	.00813	92300	.00915	82000
1000	.00739	135300	.....	.....	.....	.....
1250	.00729	171000	.00922	135500	.....	.....
1500	.00979	153000	.00960	156200	.01071	140000
1750	.01228	142200	.01228	142200	.01100	159000
2000	.....	.....	.....	.....	.01235	162000
2250	.01459	154100	.....	.....	.....	.....
2500	.....	.....	.01949	128200	.....	.....
2750	.....	.....	.....	.....	.02250	120000
.....	.....	.....	.....	.....	.....	.....
4500	.....	.....	.....	.....	.07895	57000

(These data are shown graphically in figure 6)

therefore, appear to have an equal rating. However, when refined by the three-minute step test, figure 3 shows an appreciable difference in the transition pressures which can be used to rate the samples. Samples 4, 5, and sperm can readily be rated by the transition load of figure 5. By the joint use of the one and three-minute step tests, the samples can now be rated in the order: Sperm, 1, 2, 3, 5, 4.

The three-minute step test was then run in order to determine the transition pressure. The results are listed in tables 3 and 5 and are shown graphically in figures 3 and 6, in which it is seen that, on the basis of transition pressure, the samples would be rated in the order: 1, 4, Sperm, 2, 5, 3.

The lack of agreement in the respective ratings caused much concern and, in order to obtain additional information, actual service tests were run on all oils, except sperm which was in use at the time. Samples 1, 2, and 3 each gave satisfactory performances during a run of thirty consecutive working days. When sample 4 was started, scuffing was noticed immediately on the drawn stock and, after an eight-hour run, examination of the cam and roller showed rather intense scuffing. When sample 5 was run, scuffing on the drawn stock appeared immediately on starting but, after an eight-hour run, the cam and roller were found to be in good condition. The machine was then run without the drawing operation and, at the end of forty hours, slight scuffing appeared on the surfaces of the cam and roller.

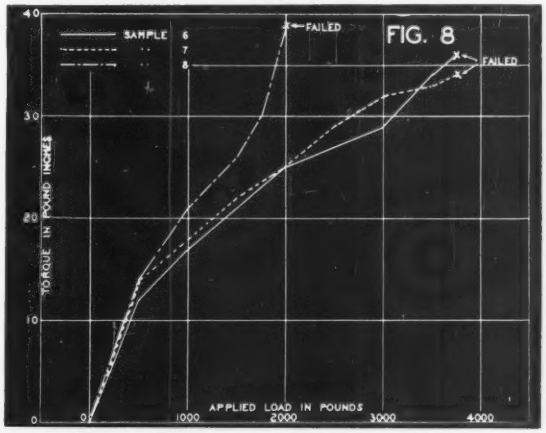
Analysis of the test and service data showed that samples 1, 2, and 3, which were satisfactory, had transition loads of 1750 lbs each, compared to 2000 lbs for the sperm oil. Of the unsatisfactory oils, sample 4 had a transition load of 1250 lbs and sample 5, 1500 lbs. From these data, it was concluded that a transition of 1750 lbs indicated satisfactory performance and that up to 50 per cent of mineral oil could be used in the lubricant.

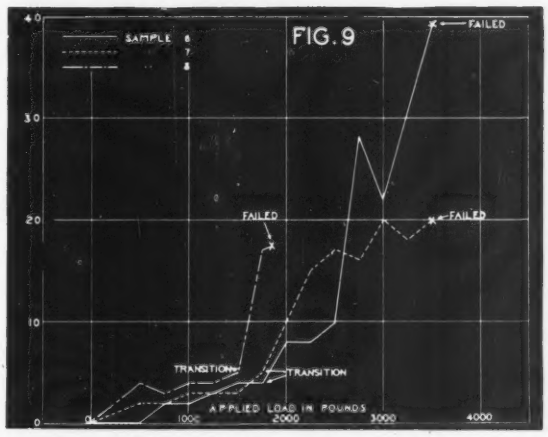
The second part of the series consisted of samples 6, 7, and 8, table 1, in which all constituents, with the exception of the sulfur additive, were kept constant. The purpose of this test was to determine the minimum amount of sulfur that could be used in the lubricant.

TABLE 6—ONE MINUTE TRANSITION LOAD STEP-UP TESTS ON SAMPLES 6, 7, AND 8

Applied Load In Pounds	Sample Number 6 Torque	6 Wear (Teeth)	7 Torque	7 Wear (Teeth)	8 Torque	8 Wear (Teeth)
500	12	0	14	2	14	4
750	15	2	16	2	16	3
1000	17	2	18	3	21	4
1250	19	3	20	3	24	4
1500	21	4	22	3	26	5
1750	23	4	23	5	30	17
2000	25	8	25	10	39—	Failed
2250	26	8	27	15		
2500	27	10	29	17		
2750	28	28	31	16		
3000	29	22	32	20		
3250	32	31	32	18		
3500	34	49	33	20		
3750	36—	Failed	36—	Failed		

(These data are shown graphically in figures 8 and 9)



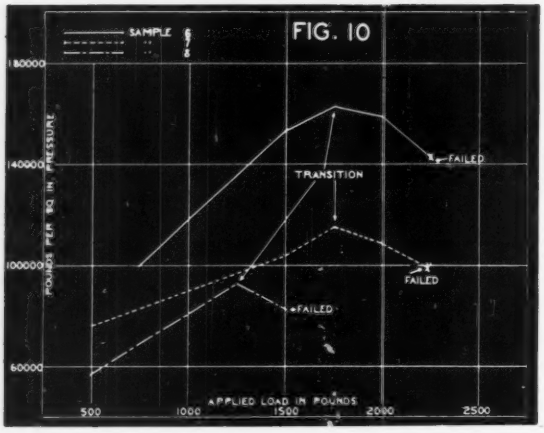


Vertical Axis Shows Wear (Teeth)

TABLE 7—Three Minute Transition Pressure Step-up Tests on Samples 6, 7, and 8

Applied Load In Pounds	Sample Number 6 Scar Area	6 Psi Pressure	7 Scar Area	7 Psi Pressure	8 Scar Area	8 Psi Pressure
500			.00653	76500	.00864	57800
750	.00748	100200	.....	.....	.....	.....
1000	.....	.....	.....	.....	.....	.....
1250					.01344	93000
1500	.00975	153700	.01440	104100	.01785	84300
1750	.01075	162800	.01517	115300	.....	.....
2000	.01235	159900	.01824	109600		

(These data are shown graphically in figure 10)



Both the one- and three-minute step tests were run and the results are listed in tables 6 and 7 and graphically shown in figures 8, 9, and 10.

Service tests were then run on samples 6 and 7. Sample 8 was eliminated from the test by reason of its having, as shown in figure 9, a transition load less than 1750 lbs. After a thirty-day run, sample 6 had given satisfactory service. When sample 7 was started, scuffing appeared immediately on the drawn stock and, after a run of forty-eight hours without the drawing operation, scuffing appeared on the cams and rollers. The only definite conclusion that could be drawn from these data at this time was that 0.5 per cent sulfur gave satisfactory performance while 0.25 per cent did not. Inasmuch as samples 6 and 7 each had a transition load of 1750 lbs, it was difficult at first to understand the difference in their respective performance. A reasonable explanation was found in the curves of figure 10 which show that sample 6 has a transition pressure (film strength) of 162,800 psi as compared to 115,300 for sample 7. This strongly suggested that a transition load of 1750 lbs would indicate satisfactory performance only when its equivalent transition pressure was not less than a fixed minimum which would necessarily have to be in excess of 115,300 psi.

A fixed minimum was established after reviewing data selected from tables 3, 5, and 7 and rearranging as in table 8.

A satisfactory minimum would naturally lie between the lowest psi pressure of the satisfactory samples and the highest psi pressure of the unsatisfactory ones. Table 8 shows that this value would be less than the 150,800 psi of sample 3 and greater than the 142,200 psi of sample 4. The rounded figure of 150,000 psi was arbitrarily selected as being of sufficient magnitude to insure satisfactory performance and was found to be adequate in actual service.

TABLE 8—psi Pressure Corresponding to an Applied Load of 1750 lbs.

Sample Number	Psi Pressure
1	182,300
6	162,800
2	161,400
3	150,800
*4	142,200
*5	142,200
*7	115,300

* Unsatisfactory in service test.

On the strength of these test results, sample 6 was selected as the alternate for the sperm oil mixture and was put into service where it has been giving satisfactory performance for a period of more than three years. From the test data it has been determined that, for the particular case just described, a transition load of not less than 1750 lbs with a corresponding transition pressure of not less than 150,000 psi indicates satisfactory performance in actual service. The oil in use is held rigidly to these requirements.

Conclusion

In all efforts to correlate test results with actual lubrication performance, it must be borne in mind that pressure values as indicated by a test instrument are not necessarily equal to those on the actual machine being lubricated. Inasmuch as the metal is equally as important as the lubricant in the region of boundary friction, differences in wear attended by differences in unit pressure will invariably result by reason of differences in the metal characteristics of instrument test parts and the metal characteristics of practical machine bearings and other relatively moving surfaces; and also by reason of the differences in the geometry of the relative surfaces. Test machine figures, therefore, are used solely as "index values." In the case just described, it has been estimated that the actual unit pressures encountered are in excess of the 150,000 psi Falex value which indicates satisfactory performance.

It is hoped that the description of the one-minute transition load step-up test and the three-minute transition pressure step-up test along with a specific example of their practical application will stimulate further researches along these lines of endeavor and in fields of lubrication other than the one described herein. It is felt that transition is a critical point in all lubricants and that its importance should be recognized in connection with measurements and investigation in the region of boundary friction.

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[2] C. A. Crowley and F. A. Faville: *"The Evaluation of Extreme Pressure Lubricants"* presented at Sectional Regional Transportation Meeting of the Society of Automotive Engineers, Chicago, Illinois, 1937.

[3] The Falex Lubricant Testing Machine is manufactured and supplied by Faville LeVally Corp., 105 W. Adams St., Chicago, Illinois.

Additional technical literature on the well established and generally accepted basic theories and concepts of lubrication was drawn upon as the source of information from which the section on "Regions of Friction" and the interpretations of the results of the "Three Minute Transition Pressure Step-up Test" were compiled. The complexity of the resulting compilation, due to the manner in which the information was entwined in the grammatical structure, was such that direct

credit could not be properly given in the body of the article. The publications, therefore, which were used as the source of information without direct credit being given, are as follows:

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Compiled by

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PART II

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137 **H. Glaubitz & K. Göcele**—„Versuche über die Entstehung des Getriebegeräusches"; *Autom. techn. Z. 45,* 175-181.

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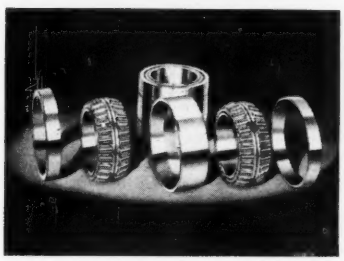

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OILS AND LUBRICANTS PATENT ABSTRACTS

Method for Removing Impurities From Mineral Oils—Patent #2,404,405—Claudius H. M. Roberts, assignor to Petrolite Corp. A process for removing water-dispersible impurities from a mineral oil of low or negligible water content, which process includes the steps of: adding relatively fresh water to said oil and mixing the added water and the oil in a first mixing step to form an oil-continuous dispersion containing the relatively fresh water in the form of droplets; later adding more relatively fresh water to said dispersion and mixing the later-added water and said dispersion in a second mixing step to disperse the later-added relatively fresh water into the oil-continuous dispersion in the form of droplets in the oil, said mixing steps being controlled in such manner that the droplets of the relatively fresh water later added are of an average size different from the droplets of the relatively fresh water added to produce an emulsion containing different-sized droplets of the water suspended in the oil; subjecting said emulsion to the action of an electric field of sufficient intensity to coalesce the water to form coalesced masses comprising impurities from the oil; and separating the coalesced masses from the oil.

Lubricant Additives and Preparation Thereof—Patent #2,404,446—Eugene Lieber and Aloysius F. Cashman, assignors to Standard Oil Development Co. Process of preparing improved extreme pressure lubricating agents which comprises solvent extracting a chlorinated paraffin alkali polysulfide reaction product containing about 5 to 10% of sulphur and about 30 to 40% of chlorine at about room temperature with isopropyl alcohol of about 91% concentration, using about 1000 cc. of the alcohol per 1200 grams of material treated, separating the raffinate phase from the extract phase, subjecting the raffinate phase to three successive extractions at room temperature with isopropyl alcohol of about 99% concentration, using about the same volume of solvent as in the first extraction phase, extracting the fourth raffinate about 125 F with isopropyl alcohol of about 99% concentration, and recovering the solvent from each of the extract phases and from the final raffinate phase.

Lubricating Compositions—Patent #2,404,871—Paul R. Van Ess, Forrest J. Watson, and Gary M. Whitney, assignors to Shell Development Co. A process for obtaining a sulfur-containing fraction possessing anti-oxidant and other valuable properties, which process comprises extracting a substantially paraffinic lubricating oil raffinate with a mercury salt under temperature conditions to produce a mercury salt-sulfur compound complex and breaking the resulting mercury salt-sulfur compound complex to regenerate and recover the extracted sulfur compounds.

A lubricant comprising a predominant amount of a refined mineral oil and characterized by a normal tendency to corrode metal bearing surfaces, and an added corrosion-inhibiting amount of a concentrate of natural-occuring sulphur-containing compounds from petroleum oil possessing anti-corrosive and other valuable properties prepared by the process which comprises extracting a substantially paraffinic lubricating oil raffinate with a mercury salt under temperature conditions to produce a mercury salt-sulfur compound complex and breaking the resulting complex to regenerate and recover the extracted compound.

Compounded Lubricant—Patent #2,405,607—Dilworth T. Rogers, assignor to Standard Oil Development Co. A lubricant comprising a mineral lubricating oil base stock and a small proportion, sufficient to stabilize said oil against deterioration, of a reaction product of a combination of the elements sulfur and phosphorus with a product obtained by reacting a phenol with a sulfur chloride derivative of an olefin.

Compounded Lubricant—Patent #2,405,608—Dilworth T. Rogers, assignor to Standard Oil Development Co. A lubricant comprising a mineral lubricating oil base stock and a small proportion, sufficient to stabilize the said oil against deterioration, of a metal salt of a reaction product of a combination of the elements sulfur and phosphorus with a product obtained by reacting phenol with sulfur chloride derivative of an olefin.

Process and Apparatus for Reclaiming Grease—Patent #2,405,705—William Robert Mobley. The method of reclaiming grease from heavier liquids which consists in filling a closed vessel to form a liquid body composed of a mixture of grease and a heavier liquid by passing the mixture into the vessel thru an inlet passage extending above the level of liquid in the vessel, separating entrained air from the liquid and venting said air from the upper portion of the vessel, discharging liquid from the vessel thru an overflow leading from the lower portion of the vessel, whereby the grease carried in the liquid is floated to the upper surface of said liquid body, forming a second body of like said heavier liquid in a closed retained position above the liquid level in said vessel and having a common inlet and outlet passage communicating with the first mentioned body of liquid at a location removed from the flow path of said liquid passing from the inlet to said overflow and remote from the zone of said air separation, whereby the air is excluded from the second body of liquid and the grease floats from the first liquid body into the upper part of said second liquid body.

The abstracts shown in this issue are from Official Gazettes — Vol. 588, Nos. 4, 5; Vol. 589, Nos. 1, 2, 3, 4; Vol. 590, Nos. 1, 2, 3, 4; Vol. 591, Nos. 1, 2, 3.

Printed copies of patents are available from the Patent Office at 25 cents each. Address the Commissioner of Patents, Washington, D. C., for copies and for general information concerning patents.

Method for removing Weakly Acidic Sulphur Compounds from Hydrocarbon Oil—Patent #2,405,872—George W. Ayers and Daniel M. Barton, assignors to the Pure Oil Co. The method of removing weakly acidic sulphur compounds from hydrocarbon oil which comprises contacting said oil with aqueous solution containing at least 5% by weight of free alkali metal hydroxide and a sufficient amount of the soluble reaction products of an alkali and high-boiling tar acids which have been freed by water washing of constitutents which react with ferric chloride in aqueous solution to impart thereto a greenish-black coloration to enhance the abilily of said solution to extract said sulphur compounds from the hydrocarbon oil.

Turbine Oil—Patent #2,405,906—Hans Schindler and Lawrence M. Henderson, assignors to the Pure Oil Co. The method of preparing an oxidation and rust inhibitor for mineral turbine oils comprising recovering from used aqueous caustic alkali solution resulting from the treatment of low-boiling hydrocarbon distillates containing sulfur and phenolic compounds with aqueous caustic alkali solution, by neutralization with an acidic substance the entire portion of "acid oil" substantially free from constituents soluble in aqueous solution of approximately pH 8, extracting said portion of the "acid oil" with a hydrocarbon solvent boiling below the boiling range of the extractable portion of the "acid oil" and separating the extract from the solvent.

Cracking and Coking of Hydrocarbon Oils—Patent #2,406,312—Joseph Mason Barron, assignor to The Texas Co. In the combination cracking and coking of hydrocarbon oils the process that comprises passing a condensate stock through a heating coil wherein it is subjected to a high cracking temperature, delivering the heated stream into the lower portion of a vertically disposed reaction chamber wherein separation of vapors from liquid residue takes place, introducing a stream of heated residual stock into an upper portion of the reaction chamber, subjecting resultant down-flowing liquid and upwardly rising vapors to counter-current contact in an unobstructed zone within the reaction chamber at cracking temperature of upward of 900 F under 200-600 pounds pressure, withdrawing the separated vapors from an upper portion of the reaction chamber at a temperature of the order of 900 F withdrawing the liquid residue from the lower portion thereof at a temperature of the order of 920 F at a rate adequate to prevent the accumulation of liquid residue therein, delivering the withdrawn residue to a coking zone wherein the pressure is reduced to a low pressure not exceeding about 50 pounds and wherein a temperature approximating 850 F is maintained by means of the hot residue introduced to thereby effect coking solely by the contained heat of the residue, subjecting said vapors withdrawn from the reaction chamber to fractionation to separate lighter products from higher boiling reflux condensate, cycling said reflux condensate to the aforesaid heating coil, subjecting evolved vapors from the coking zone to dephlegmation with a residual charging stock to form a resultant mixture of reflux condensate and unvaporized residual charging stock, passing said mixture of reflux condensate and unvaporized residual charging stock through a heating coil wherein it is heated to a temperature of the order of 800-900 F and directing the heated mixture to the upper portion of the aforesaid reaction chamber as the residual stock introduced therein.

Modification of Fatty Oils—Patent #2,406,337—Laszlo Auer. A process for treating fatty oils having drying properties, to improve their film-forming characteristics when used as components of surface coating materials, which process comprises incorporating in the oil up to 30% of a polyhydroxy benzene as the sole active treating agent, and heating the mixture at a temperature between about 75 C and about 350 C but not above the boiling or decomposition point of the oil, whichever is lower, for at least 30 minutes.

Lubricant Containing Condensation Product—Patent #2,406,549—Eugene Lieber, assignor to Standard Oil Development Company. A lubricant comprising a major proportion of lubricating oil and a pour-depressing amount of a Friedel-Crafts condensation product of an aromatic compound and a saturated ester having less than 10 carbon atoms, said condensation product being soluble in mineral oils, and substantially non-volatile at temperatures up to 600 F under fire and steam distillation.

Compounded Lubricating Oil—Patent #2,406,564—Dilworth T. Rogers and John G. McNab, assignors to Standard Oil Development Co. An organic material containing a stabilizing quantity of a reaction product of at least 2 gram atoms sulfur with 1 mol of a compound having the structure—

ArXMT

where Ar is an aromatic nucleus, X is a non-metal of group VI of the periodic table, M is a divalent metal of group II of the periodic table and selected from the class consisting of calicum, barium, strontium, magnesium and zinc, and T is a member of the class consisting of OH and $(OM)_nXAr$, where M, X and Ar have the meanings given above and n is a number of the class consisting of 0, 1, and 2.

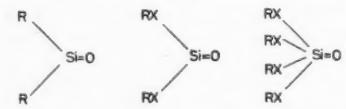
As a composition of matter a sulfur-containing product obtained by reacting at least 2 atomic proportions of elemental sulfur with one molecular proportion of metal phenate in which the metal is a divalent metal of group II of the periodic table and selected from the class consisting of calicum, barium, strontium, magnesium and zinc.

Preparation of An Improved Lubricant—Patent #2,406,575—David W. Young and Harris D. Hineline, assignors to Standard Oil Development Co. An improved lubricant comprising in combination a hydrocarbon material and a solute therein comprising .5% to 20% of a cyclicized, phosphorous pentasulfide treated, polymer of a polyolefin having 6 to 14 carbon atoms per molecule, a molecular weight between 3000 and 100,000 and an iodine number after cyclicizing between 5 and 50.

Conversion of Hydrocarbon Oil—Patent #2,406,613—Edward C. Lee, deceased, late of Chicago Ill., by James T. Cullinan, administrator, and Charles L. Thomas, assignors to Universal Oil Products Co. A conversion process which comprises subjecting a hydrocarbon oil at conversion conditions to the action of a composite catalyst comprising silica, alumina and zirconia prepared by hydrolytically absorbing alumina and zirconia on a purified silica hydrogel and heating the resulting mass to remove a major portion of its water content.

Conversion of Hydrocarbon Oil—Patent #2,406,614—Edward C. Lee, deceased, late of Chicago, Ill., by James T. Cullinan, administrator, and Charles L. Thomas, assignors to Universal Oil Products Co. A conversion process which comprises subjecting a hydrcarbon oil at conversion conditions to the action of a catalyst comprising silica, alumina, and zirconia prepared by compositing a purified silica gel with decomposable salts of aluminum and zirconium and heating said composite to decompose said sals and form the oxides thereof.

Cutting Oil—Patent #2,406,671—Hyman Diamond, assignor to Shell Development Co. An oleaginous composition capable of forming oil-in-water emulsions, which composition contains a foam-reducing amount of an associated compound selected from the group consisting of



wherein each R is a saturated, non-aromatic organic radical and X is selected from the group consisting of oxygen, sulfur, selenium and tellurium atoms, the total number of carbon atoms in the R's associated with each Si atom being at least 24.

Purification of Oil-Soluble Sulphonates—Patent #2,406,763—William K. Griesinger, assignor to The Atlantic Refining Co. The method of purifying oil-soluble petroleum sulphonates containing inorganic salts and water, which comprises contacting said sulphonates with from 2 to 6 volumes of low viscosity hydrocarbon solvent which dissolves the sulphonates but not the salts and with 0.02 to 0.1 volume of a lower aliphatic alcohol, and separating the resulting solution of purified sulphonates from the inorganic salts and water.

Lubricated Traveler Ring—Patent #2,406,901—Frank S. Pollock, Jr., assignor to E. I. duPont deNemours and Co. A twister ring assembly comprising in combinaton a ring rail, a traveler ring mounted on the ring rail, means for conducting lubricant to the face of said traveler ring, lubricant collecting means disposed immediately below said traveler ring and in the path of lubricant thrown from said traveler ring, said lubricant collecting means comprising an annular felt pad and means for conducting lubricant from said collecting means to said means for conducting lubricant to the face of said traveler.

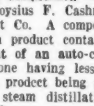
Lubricant and Process of Lubricating Surfaces Therewith —Patent #2,406,971—Frank J. Sowa. A lubricant comprising a non-lubricating organic liquid and an organic silicon compound selected from the class of hydrolysis products of organic silicanes and polymers of said hydrolysis products, said organic silicon compound being present in an amount sufficient to impart lubricating properties to said liquid.

Lubricant and Process of Lubricating Surfaces Therewith —Patent #2,407,037—Frank J. Sowa. The method of lubricating relatively moving metallic surfaces which comprises maintaining between the bearing surfaces a lubricant film comprising a hydrolysis product of an organic silicane.

Mineral Oil Lubricating Composition—Patent 2,407,087—Eugene Lieber and Aloysius F. Cashman, assignors to Standard Oil Development Co. A composition comprising as a base a hydrocarbon product containing hydrocarbon wax and a small amount of an auto-condensation product of an aliphatic ketone having less than 12 carbon atoms, said condensation product being substantially nonvolatile under fire and steam distillation conditions at temperatures below 600 F.

Method of Purifying Oil Field Waters—Patent #2,407,180—Harold Schiller and Abraham Shapiro, assignors to Socony-Vacuum Oil Co., Inc. The method of removing clay-suspended petroleum from oil-field water, which comprises: passing said water by controlled flow through a bed composed of granules of ferrous sulfid (FeS) and thereby transferring said petroleum from said clay suspension to the granules composing said bed; passing substantially oil-free clay particles from said suspension out of said bed into suspension in the effluent water and retaining the petroleum in said bed.

Processes for Resolving Oil-In-Water Emulsions—Patent #2,407,895—Louis T. Monson and William W. Anderson and Fred W. Jenkins, assignors to Petrolite Corp, Ltd. A process for breaking petroleum emulsions of the oil-in-water type, characterized by subjecting the emulsion to the action of a surface-active heat-polymerized amino-alcohol of the formula:



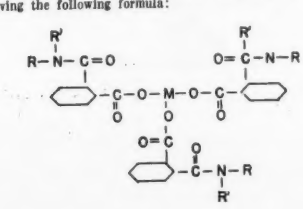
Wherein OR is an alkylene oxide radical having not over 4 carbon atoms and selected from the class consisting of ethylene oxide radicals, propylene oxide radicals, butylene oxide radicals, glycid radicals and methyl glycide radicals consisting of hydrogen atoms and alkyl radicals having 6 carbon atoms or less; m represents a numeral varying from 0 to 3; n represents the numeral 2 or 3; and n′ represents the numeral 0 or 1, with the proviso that n+n′=3; said heat polymerized compound being selected from the class consisting of the anhydro base, the hydrated base, and salts.

Lubricating Composition—Patent #2,407,954—Merrell R. Fenske and George H. Cummings, assignors to Rohm and Haas Co. A lubricant comprising a lubricating oil and an oil-soluble, polymerized ester of the general formula—

wherein X is a member of the class consisting of hydrogen and the methyl group, and R represents a saturated hydrocarbon group of at least five carbon atoms, said polymerized ester being present in an amount sufficient to improve the lubricating properties of the oil, and a hydrocarbon oil-soluble, alcoholic hydroxyl-containing ester of a polyhydric aliphatic alcohol and a long chain fatty acid in an amount sufficient to reduce substantially the emulsifying tendency of the oil containing said polymerized ester alone.

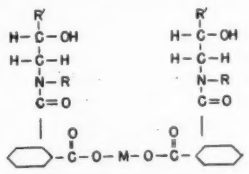
Lubricating Oils—Patent #2,408,090—Sidney Musher, assignor to Musher Foundation, Inc. A process of improving lubricating oils to decrease sludge formation and also to decrease their tendency to cause corrosion of metal surfaces which comprises treating the entire body of such oil with a relatively small amount of phosphatide and a mononuclear aromatic sulfur containing compound sufficient to decrease sludge formation of the said oil.

Oil Compositions—Patent #2,408,102—Herschel G. Smith and Troy L. Cantrell and John G. Peters, assignors to Gulf Oil Corp. An improved mineral oil composition comprising a major amount of a mineral oil and a minor amount of an oil-soluble trivalent metal salt of N-alkyl, alkylol ortho phthalamidic acid, said metal salt having the following formula:



Wherein M is a trivalentmetal, R is an alkyl group and R′ is an alkylol group, and the amount of said metal salt being sufficient to impart corrosion-inhibiting properties to the improved oil composition.

Mineral Oil Composition—Patent #2,408,103—Herschel G. Smith, Troy L. Cantrell, and John G. Peters, assignors to Gulf Oil Corp. An improved mineral oil composition comprising a major amount of a mineral oil and a minor amount of an oil-soluble divalent metal salt of N-alkyl, alkylol ortho phthalamidic acid, said metal salt having the following formula:



Wherein M is a divalent metal, R is an alkyl group containing 8 to 22 carbon atoms and R′ is hydrogen or an alkyl group, and the amount of said metal salt being sufficient to impart corrosion-inhibiting properties to the improved oil composition.

Drill Lubricant—Patent #2,408,385—Edmund L. Flood, assignor to Consolidated Vultee Aircraft Corp. A drill lubricant composition comprising, on a weight basis, from 45 to 52% of a soda base grease, 38 to 43% of paraffin wax having a melting point of at least about 143 F., 8 to 12% of turpentine and 0.25 to 0.5% of aluminum stearate.

Decolorizing Oils and Agents Therefor—Patent #2,408,454—Frances Michael Sullivan. The method of treating a glyceride oil containing its natural color bodies to decolorize the same which comprises intimately contacting said glyceride oil with a preformed hydrous alkali metal soap of saturated and unsaturated fat acids, the unsaturated fat acid constituting at least 30% of the soap forming acids, and the amount of saturated fat acid being sufficient to produce ready separability of the soap from the oil, the soap being dispersed through the oil in finely divided condition, the soap being separable from the oil, and separating the soap carrying the color bodies from the treated oil.

Slushing Composition—Patent #2,408,971—Gordon W. Duncan, assignor to Standard Oil Development Co.

A slushing oil composition consisting of a petroleum fraction to which is added degras, a metal salt of oil-soluble sulfonic acids derived from petroleum by treating petroleum stocks with concentrated sulfuric acid and from 1 to 10% of a compound having the formula

R—O—alkylene—O—R′

wherein R is selected from the group consisting of hydrogen and alkylol radicals; and R′ is selected from the group consisting of hydrogen, alkyl, and aryl radicals.

Treatment of Wax-Oil Mixtures—Patent #2,408,977—Adam H. Gebauer, assignor to Tide Water Associated Oil Co. A continous process for deoiling wax which comprises continuously supplying a flowable stream of a wax-oil slurry under pressure to a filtering surface, propelling the slurry along said filtering surface in a confined channel while progressively filtering oil therefrom to separate a semi-solid wax and while progressively compacting the separated wax to form a seal of deoiled wax at the end of said channel, and continuously removing deoiled wax from said seal at a rate substantially equal to its rate of formation.

In apparatus of the character described, the combination of means for forming a wax-oil slurry, an extrusion filter including a filtering medium through which the oil is extruded and means for continuously propelling the wax filtering out on said medium along the length thereof, means for continuously introducing the slurry to the inlet end of the filter at a pressure such as to cause the wax particles to agglomerate and to filter out as a plastic wax product and for continuously and separately discharging the wax product and the oil filtrate from the other end of the filter, and means for progressively compacting the plastic wax product as it is propelled through the filter to a selected consistency such that the compacted wax forms a solid wax seal at the discharge end of the filter which prevents channeling of the initially plastic wax product.

Treating Emulsions—Patent #2,409,005—William O. Weber, assignor to Standard Oil Development Co. A method for treating salt-bearing crude oil comprising the steps of heating the oil, adding water to the heated oil and agitating in order to form an intimate admixture of the oil and water and to dissolve the salt from the oil into the water, contacting a bed comprising water-wettable, finely divided solids with a basic solution having a concentration within the range of .0125 to .25 per pound mole per 1,000 gallons of water in order to insure the thorough water-wetting of the bed, passing the mixture of oil and water through said treated bed and subsequently settling the mixture into a water component and into an oil component suitable for feeding to a distillation unit.

Process for Refining Mineral Oils—Patent #2,409,059—James V. Montgomery, L. Barrett Goodson, and Robert W. Henry, assignors to Phillips Petroleum Co.

The process of solvent extraction of mineral oils including the steps of mixing the oil with a solvent mixture comprising a hydrogenated selected fraction of commercial pyridine, an anti-solvent, and water, the selected fraction of commercial pyridine boiling between the approximate limits of 240 and 500 F., and the hydrogenated material consisting essentially of pipecolines and the antisolvent being acetone, thereby forming a raffinate phase and an extract phase, and separating the raffinate phase from the extract phase.

Process of Separating Tall Oil Into Fractions by Treatment with Levulinic Acid Ester—Patent #2,409,137—Kermit D. Longley, assignor to Quaker Chemical Products Corp.

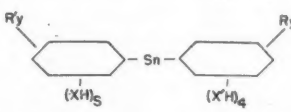
The process of separating tall oil into useful fractions which comprises mixing tall oil with a liquid ester of levulinic acid to form an apparently homogeneous solution, allowing the solution to stand at approximately normal room temperature until a waxy solid precipitates, separating the precipitate from the supernatant, and cooling the supernatant to substantially below room temperature whereby a fraction consisting largely of fatty acids precipitates.

Lubricants—Patent #2,409,296—Rush F. McCleary, assignor to The Texas Company.

A lubricant comprising a hydrocarbon oil and a small quantity, less than 5% by weight, of an oil-soluble sulfurized derivative of partially hydrogenated cardanol.

Lubricating Oil—Patent #2,409,303—John R. Morris and Rush F. McCleary, assignors to The Texas Company.

A lubricating composition comprising a mineral lubricating oil having incorporated therein 0.1-5.0% by weight of an oil-soluble metal derivative of a compound of the formula



In which R and R′ are radicals selected from the group consisting of alkyl, aralkyl, cycloalkyl and naphthenyl, the alkyl portion of which contains at least 5 carbon atoms, X and X′ are elements from the group.

Lubricant and Method of Preparing Same — Patent #2,409,333—Donald L. Wright and Charles W. Bohmer, Jr., assignors to Standard Oil Development Co.

A chemically resistant lubricant having approximately the following composition in per cent by weight:

	Per cent
Mineral white oil	50—85
Petrolatum (light oil-free)	10—50
Paraffin wax	0—10

and an amount of a viscosity-increasing linear polymer of an oxygen-containing aliphatic compound, said amount being selected according to the average molecular weight of said polymer, indicated by the following table:

Average mol. wt. of polymer	Per cent by weight
5,000	10—50
12,000	8—20
30,000	7—15
80,000	5—10
150,000	0.3—2

Emulsion—Patent #2,409,338—William H. Alton and Francis E. Hutchins, assignors to R. T. Vanderbilt Co., Inc.

An oil-in-water emulsion suitable for use in cosmetic and pharmaceutical preparations comprising about 1%-65% of a viscous petroleum oil, about 34%-98% of water and about 0.75%-10% of the solids of an inorganic jelly produced as the aqueous effluent by centrifuging an aqueous suspension of a swellable clay containing 5%-10% by weight of solids at 800-1500 g.

Instrument Lubricant—Patent #2,409,443—John D. Morgan and Russell E. Lowe, assignors to Cities Service Oil Co.

A lubricant for instrument bearings or the like comprising tricresyl phosphate and ethylene glycol monobenzyl ether in about equal percentages by weight.

Clock Lubricant—Patent # 2,409,444—John D. Morgan and Russell E. Lowe, assognors to Cities Service Oil Co.

A lubricant consisting essentially of a mixture of from 40 to 60 per cent of tricresyl phosphate, from 25 to 15 per cent of dibutyl phthalate, and from 35 to 25 per cent of triethylene glycol di-2- ethylbutyrate, all of said percentages being by weight.

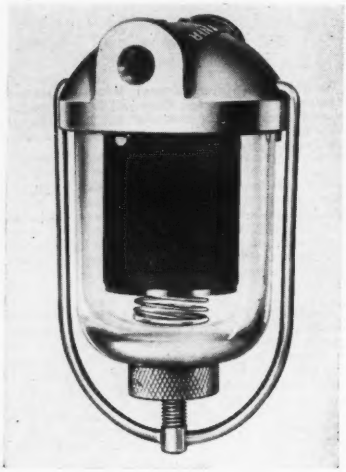
Second Annual Meeting
March 17, 18, 19, 1947
Hotel William Penn
Pittsburgh, Pa.

New Skinner Purifier Separates Free Water From Gasoline

An important advance in automotive design resulting from wartime research has just been announced by Skinner Purifiers, Inc., Detroit 11, Mich. This is the Skinner Gasoline Purifier, a system of purification said to be so unusually efficient that it became one of the most widely used filtration devices of the armed forces. Several hundred thousand Skinner Purifiers were used in aircraft, land vehicles, and naval units and their use is being continued in most of the new commercial planes as well as many of the finer automotive products.

The Skinner Purifier is made in one model to fit almost all applications—cars, trucks, buses, tractors, stationary engines and fuel oil burners. As explained by Mr. Ralph Skinner, president of Skinner Purifiers, Inc., the purifying action is as follows:

The Skinner Purifier purifies gasoline or other fuel by passing it between layers of helically wound ribbons made from impervious material. Dirt and other impurities are stopped at the outer edges of these ribbons and fall into the sediment chamber. Any accumulations on the outer surface of the cylinder of helically wound ribbons occurring after long use can be quickly cleaned off by simply blowing compressed air, or even the breath into the cylinder.



The Skinner Purifier separates free water from gasoline according to the manufacturer. This phenomenon can be attributed to the laminated construction of the "Kwick Klean Kartridge" with its almost innumerable orifices of a few microns in size, and the differences in surface tension and specific gravity of the two liquids.

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GRAPHITE
DEGRAS
WOOL GREASE
LANOLIN
600 NORTH WELLS STREET
TELEPHONE MICHIGAN 3155
CHICAGO 10, ILLINOIS

Tank Solvent

"Siloo" fuel oil tank solvent is announced by Petroleum Solvents Corp., 331 Madison Avenue, New York 17, N. Y. It is claimed to be effective in dissolving sludge accumulations and preventing rust and acid formation.

For use with medium and large Diesel engines, the manufacturer recommends an initial application of one gallon to every thousand gallons of fuel, subsequent application to be at the rate of one gallon per 6000 gallons of fuel oil.

"Siloo" is said to be neither inflammable, corrosive, nor toxic, although it is completely miscible with fuel oil, and its addition does not affect the properties of the oil.

Rustproofing Process

Calgon, Inc., of Pittsburgh, Pa., has just announced a new low-cost rustproofing technique for steel and galvanized steel, known as the Banox process, which not only will protect metal during the manufacturing stages but permit a tighter bond with paints, and give it longer life through greatly enhanced corrosion resistance.

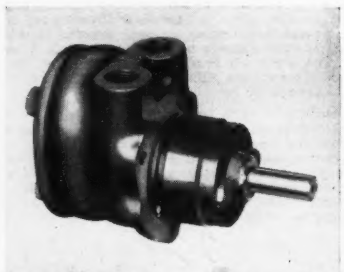
The basis of this new chemical process is a flexible, glassy metal phosphate coating, so plastic that it will bend with the steel or permit die-stamping without harm to the coating. The coating, which has a thickness of from 5 to 15 millionths of an inch, may be put on by the spray, immersion, or brush methods. It requires no heat.

The process promises great improvements in the finishing of automobiles, refrigerators, gas and electric ranges, deep-freezing units, stokers, household appliances, and other metal articles. Greater finish durability and a longer service-life to the ultimate customer is assured.

Many branches of the steel business may find it of interest. The process can be used by the primary steel manufacturing plant, by the converter, and by the final fabricator of consumer goods.

Rotary Pump

The George D. Roper Corporation of Rockford, Illinois, announces the Series K. Rotary Pump in three sizes up to 3 gpm at 150 psi and 1740 rpm. These pumps are available with built in relief valves and either mechanical seals or packing glands, and can be arranged for hub, flange, or foot mountings by means of interchangeable mounting brackets and adapters. Drive may be direct connected, chain, belt or gear. They can be operated in either direction.



These pumps are said to be suitable for a wide variety of applications including Diesel fuel oil transferring and pressure lubrication. Details are given in Bulletin No. 10.

Texaco Announces Extensions to Regal Oil Line

Announcement of three additions to the well known Regal Oils which are designed for turbines, hydraulic and circulating systems, has been made by The Texas Company.

The new lubricants are classified as Regal Oils (R&O) AZ, F, and G. Regal Oil (R&O) AZ is said to be suitable for use in hydraulic equipment in sub-zero temperatures, and F and G are developed for use in mills where rust and oxidation inhibited oils of corresponding viscosity are needed.

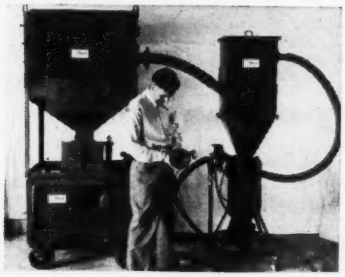
The Regal Oils (R&O) are rust and oxidation inhibited oils which prevent clogging of oil lines, scoring of journals, and sticking of governors in marine and stationary turbine installations as well as rusting and sludging in hydraulic and circulating systems at both idle and operating temperatures, according to the manufacturer.

A new graphite type grease developed for use under extremely low temperature conditions primarily for service in rail lubricators manufactured by the Maintenance Equipment Company has also been announced by The Texas Company. Known as GREASE 904-W, it is suitable for winter service in northern climates and will give excellent performance at temperatures as low as –50° F.

Blast Cleaning Device

The Vacu-Blaster, an entirely new blast-cleaning device that promises to revolutionize methods of cleaning or refinishing metal, concrete, or other hard surfaces, is now in production by the Vacu-Blast Co., Inc., 1054 Broadway, Burlingame, Calif.

Unique feature of the Vacu-Blaster is its vacuum return system, which permits no abrasives or other particles to escape into the open. It now becomes possible to blast-clean under conditions that once would have prohibited the use of this means of removing corrosion and other deposits.



Operated in much the same fashion as a simple household vacuum cleaner, the Vacu-Blaster may be used without special precautions or preparations according to the manufacturer. There need be no interruption of other operations or business in the immediate vicinity. The vacuum pick-up system is said to be so positive in action that machinery, food products, or other objects need not be removed or even covered although they may be adjacent to an operating Vacu-Blaster.

Many types of abrasives may be used, depending upon the nature of the work to be done and the finish desired. Spent abrasive is reclaimed by the Vacu-Blaster and re-used as long as it remains effective.

Operation of a Vacu-Blaster is predominantly automatic. The blast is controlled by a switch at the gun through which the abrasive blast is directed and through which grit and dust are picked up. The vacuum system operates continuously returning grit and refuse to the reclaiming tank, where re-usable grit is returned to the blasting system while dust and refuse are shunted off to a dust collector.

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Shaft Seal

A new type of oil seal packing, now being manufactured by Johns-Manville at Manville, N. J., has been developed by the Johns-Manville Research Laboratories for the protection of bearings, according to H. R. Poulson, manager of the packing department.

Using no metal, the new oil seal is said to have a high factor of heel rigidity and a soft flexibility. It is made with a heel of resin-bonded fabric, giving it the rigidity essential for a press fit in the cavity and with a lip of a tough but soft flexible compound. The special lip design makes it possible to vary the bearing area and control the pressure of the lip against the shaft by means of a garter spring, thereby reducing shaft wear to a minimum.

Its one-piece precision-made body, concentrically molded and non-metallic in construction, permits relatively liberal machining tolerances. Its compact shape makes possible a light flange section that effects compactness of machine design.

In service, these features of the Johns-Manville Clipper seal are said to provide a positive lubricant-retaining, dirt-excluding seal, automatic in operation, adaptable to a wide range of conditions, and highly resistant to most forms of corrosion.

Clipper Seals are made in sizes for shafts from 1 5/16-inch to 37-inch diameter, in both endless and split types. Special designs are available where unusual temperature, pressure or chemical conditions required.

Die Lubricant

Die Slick No. 11 is a new lubricant for pressure die casting dies developed by G. W. Smoth & Sons, Inc., 5401 Kemp Road, Dayton 3, Ohio, manufacturers of lubricants and supplies for the die casting industry.

Its use is said to guarantee a clean, spotless zinc casting with a satin-smooth surface finish. It is a colorless, odorless compound that is non-staining, non-corrosive, non-carbon-forming and causes no objectionable smoke or gases. Just a fine mist spray of the lubricant is applied to the die. It eliminates scoring and sticking and assures easy ejection of the casting. It prevents formation of zinc oxide on the core pins and die cavities. An important feature about Die Slick No. 11 is that it is said to leave no undesirable deposit on the casting that might prove detrimental to subsequent plating of the zinc casting.

Die Slick No. 11 is packed in 1-gallon and 5-gallon pails and 55-gallon drums.

New Bulletins

The Sun Oil Company, Philadelphia 3, Pa., has recently issued a revised edition of its Technical Bulletin, ***"Lubrication of Diesel Engines.*** The 48-page booklet covers the history of the Diesel engine, the fundamentals of design, the types and advantages of the two-stroke and the four-stroke engine.

Fuel injection systems and the combustion principle are discussed in detail, illustrated by photographs and drawings. Lubrication problems are also featured. Twenty-six pages of the booklet are, however, taken up with operating principles that should prove valuable to Diesel engine owners.

Much up-to-the-minute information on modern Diesel lubricants is given in the technical bulletin. A chart showing lubricating oil recommendations for several types of Diesels is contained in the book, and specific problems of individual engines are discussed.

Maintenance and operating problems of Diesel engines, such as ring sticking, bearing failures and oil contamination, are covered in the final section of the booklet. A two-page, easily read trouble shooting chart is also included.

A copy may be obtained from Sun Oil Company, 1608 Walnut Street, Philadelphia 3, Pa.

New technical booklet on colloidal graphite and its uses—in lubrication (high-temperature, low-temperature and dry), parting, surface coating, impregnation, and such. Sixteen pages; 3-color; 5 extended specification tables regarding dispersions in water, oil, hydrocarbons, alcohol, and special organics. Over 25 illustrations of applications. Interpretations of the 19 fundamental properties of colloidal graphite. Photomicrographs of the material. Complete reference and indexing to 12 specialized technical bulletins, 6 published reports and 5 pieces of application literature. Copies available through Acheson Colloids Corporation, Port Huron, Michigan.

In industry the most frequent applications for colloidal graphite dispersions are said to be: dry-film lubrication, oil additives for boundary conditions, running-in new equipment, the lubrication of forging and extruding dies, and cutting fluids.

L. B. Perkins has been made Assistant Manager, and F. J. Schmitt has been made Director of Sales of D. A. Stuart Oil Co., Chicago, manufacturers of cutting fluids and lubricants. Mr. Perkins has been Secretary-Treasurer since 1944, and Mr. Schmitt has been Sales Manager since 1942. C. N. Cox, formerly of Archer-Daniels-Midland Co., is the new Sales Manager. J. E. McCoy, formerly Assistant to the Sales Manager, becomes Assistant to the Director of Sales.

Articles Scheduled for Publication in Future Issues of *Lubrication Engineering*

Aug, W. F., *User Reactions Toward Additive Oils.*

Egan, Edward G., *A Synthetic Lubricant for Hydraulic Fluid.*

Bauer, Walter C., *Oil Filtration.*

Churchill, L. R., *Extreme Pressure Lubricants — Their Development and Utility in Industrial Lubrication.*

Whitehead, D. E., *The Spraying of Gear Lubricants.*

Ryan, V. A., *Incipient Seizure.*

Johnson, W. A., *Coolants, Lubricants and Their Industrial Application.*

Frohman, O., *Bearings.*

Schultz, R., *Bearings.*

Meyer, A. E., *Lubricating Pressed Metal Production Machinery.*

Bondi, A., *The Relationship Between Flow, Chtracteristics and Chemical Structure of Lubricants.*

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A.S.L.E. SECTION ACTIVITIES

Los Angeles Section

The Los Angeles Section was formally organized on Friday, August 16, 1946, at a meeting held in the Mechanical Engineering Building of the California Institute of Technology in Pasadena. Dr. R. G. Larsen, Western Regional Vice President of A.S.L.E., opened the meeting and appointed a Nominating Committee to select officers for the remainder of the year 1946. This Committee consisted of:

Mr. Phil Adams (General Petroleum)
Mr. R. L. Engel (Allis Chalmers)
Mr. E. F. Hensley (Dow Chemical)
Mr. P. Kyropoulos (California Institute of Technology)
Mr. J. G. Nordin (Southern California Gas Company)

Officers of the Los Angeles Section, A.S.L.E. Standing, left to right: R. L. Engel, J. G. Nordin, E. F. Hensley, Phil Adams. C. W. Ashman. Seated: M. E. Wise, D. H. Moreton, Peter Kyropoulos, L. G. Kline, R. G. Larsen.

While the Nominating Committee was preparing its recommendations, Dr. Larsen addressed the group telling of the Society and its objectives.

The names presented by the Nominating Committee were approved by the group in attendance and the following men then took office:

Chairman: Mr. D. H. Moreton (Douglas Aircraft)
Vice Chairman: Mr. L. G. Kline (Dow Chemical)
Secretary-Treasurer: Mr. P. Kyropoulos (California Institute of Technology)
Program-Planning: Mr. M. E. Wise (General Petroleum)
Membership: Mr. C. W. Ashman (Shell Oil Company)
Advisory Committee:
Mr. Phil Adams (General Petroleum)
Mr. R. L. Engel (Allis Chalmers)
Mr. E. F. Hensley (Dow Chemical)
Mr. A. A. Lieberman (Petroleum Marketing Company)
Mr. J. G. Nordin (Southern California Gas Company)

Organization Meeting, Los Angeles Section, August 16, 1946.

Following this there was a general discussion of the Society in which Mr. Phil Adams discussed the historical background of A.S.L.E. and Mr. Spyro Kyropoulos discussed the status of lubrication research. It was announced that the first technical meeting had been planned for September 3rd.

At the September 3rd meeting, Mr. W. E. Thill and Mr. R. A. Watson, both of Federal Mogul, presented a paper entitled "Practical Aspects of Sleeve Bearing Materials." This paper was originally presented at a Seattle meeting of the S.A.E.

The next meeting was held in the Ethyl Building, Los Angeles, on October 7, 1946. The speaker was introduced by Mr. Charles A. Fine of the Alemite Corporation, who demonstrated with a few production statistics the importance of reducing shut-down of equipment for maintenance and repair. He pointed out in what respect centralized lubrication contributed to the reduction of shut-down periods.

The main topic for the meeting wa "Centralized Lubrication" by J. W. Frier, of the Alemite Corporation. Mr. Frier traced machinery lubrication from the simple oil hole with gravity and capillary feed to the modern, fully automatic high pressure lubrication system. He then outlined the principal design requirements for a centralized lubrication system and showed how these requirements were met by the different components of a modern lubrication system. Several demonstration models illustrated different basic distributing systems built up of similar components. This demonstration showed different dispensing mechanisms (grease guns) including a fully automatic system. Application of the various systems to existing and new machinery was illustrated by slides.

A discussion ended the meeting in which a number of details were further explained.

The next meeting was held November 19th in the Ethyl Building, Los Angeles. The topic for discussion was "Practical Problems of Lubrication of Marine Turbines." This was fully discussed by three speakers, Frank W. Pollard (Mechanical Engineer), William L. Bridge (Steam Service Supervisor), and Donald R. Jenkins (Pacific Coast Steam Engineer), all of the Westinghouse Company. The topic was adequately presented by the speakers and followed by an interesting discussion from those in attendance.

Milwaukee Section

The first meeting of the new season was held on September 16th. The speaker of the evening was Mr. R. W. Kolderman of the Dow Corning Corporation who spoke on "Silicone Lubricants." All of the 100 who attended the meeting were extremely interested in the fine presentation Mr. Kolderman made of this interesting subject.

Mr. Oscar Frohman, Chairman of the Section, announced that arrangements had been completed wherein the Milwaukee Section of A.S.L.E. is now affiliated with the Engineering Society of Milwaukee. Future meetings of the Section will be held at the Engineering Society Headquarters in their beautiful new building at 3112 West Highland Boulevard.

At the meeting of October 21st, Mr. Frank Ross of the E. F. Houghton Company was speaker. His subject of "Confused Lubrication" was extremely interesting and clarified many points.

The November meeting was held on the 18th with Mr. F. L. Matthews of the Monsanto Chemical Company speaking on the topic "Custom Building of Crankcase and Gear Oils with Additives."

The talk was well received and elicited very interesting comments and discussion. Mr. Mathews is very well informed and has had a great deal of experience with additives, and this subject is of course of great interest to lubrication engineers.

The last part of the meeting was taken up by a discussion of the conducting of training programs for lubrication men in industry.

Cleveland-Youngstown Section

The first regular business meeting of the 1946-47 season was held on Tuesday, October 8th, in the English Room of the Hotel Carter, to coincide with Mr. Bergstrom's presence in Cleveland with forty-three in attendance. Hereafter the regular meetings will be held in the Engineering Society headquarters on the established meeting night — the fourth Tuesday in the month.

Mr. A. G. Bergstrom, Staff Engineer for the Socony Vacuum Oil Company in New York City, an authority in his field, presented his paper entitled "Hydraulic Oils." This was well received and provoked considerable open discussion.

Following Mr. Bergstrom's talk, Mr. Frank Sargent showed slides to supplement the discussion.

The Section will hear Dr. Eugene Lieber, Technical Director for the Nox-Rust Chemical Corporation, speak on the subject "Modern Rust Preventive Snares the Fingerprint" at the November 26th meeting. Mr. G. A. Daubert, President of the Nox-Rust Corporation, is also expected to be present at the meeting.

New York Section

The first meeting of our 1946-47 Fall-Spring Session was a Dinner Meeting and was held in the Midston House, New York City at 6:30 P.M., October 3. Seventy-six members and guests attended this Dinner while a total of 125 attended the Meeting. The paper of the evening was delivered by Mr. Frank L. Bradley, Plant Engineer, Forstmann Woolen Co., Passaic, N. J. His topic was "The Lubrication of Textile Machinery."

His paper was a Lubrication Engeneer's "Cooke's" Tour through a wool mill and highlighted all of the processes, machinery, and lubrication problems. Machinery, as well as present lubrication problems, were illustrated by lantern slides. Of particular interest were Mr. Bradley's lubrication charts of some of his equipment. Following Mr. Bradley's talk, Mr. D. D. Fuller, Chairman, introduced Mr. F. Norton, Hyatt Bearing Division, General Motors Corp.; Mr. F. Jones, Socony-Vacuum Co.; Mr. W. O. Wright, Bijur Lubricating Corp.; Mr. W. B. Myers, Manzel Bros. These men commented on Mr. Bradley's paper.

This was one of the finest meetings which we have had to date and was very well attended by engineers from all phases of industry.

Pittsburgh Section

Mr. G. L. Davis reports that the Pittsburgh Section held its regular September meeting at the Webster Hall Hotel on September 20. Dinner was served to fifty and several dropped in later for the business meeting.

Mr. Svenson appointed Messrs. White, Sumner, Bright and Lamport as a committee to make arrangements for the national convention to be held in Pittsburgh during March, 1947. Mr. Svenson also appointed Messrs. Ennis, Lewis, Weinkauf, and Fink to act with him as the industrial membership committee.

Dr. Mahncke then introduced Mr. C. C. Davenport of the Westinghouse Electric Corporation who gave a very informative talk on the "Problems Encountered in the Lubrication of Gas Turbines." After an informal question and answer period the meeting adjourned.

A.S.L.E. Section Officers

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PITTSBURGH:	Chair., Mr. E. B. Svenson, Sr., Aluminum Co. of America, New Kensington, Pa. V. Chair., Mr. Mark A. Stillwagon, Carnegie-Illinois Steel Corp., Homestead, Pa. Secy.-Treas., Mr. George H. Davis, Shell Oil Co., 1102 Grant Bldg., Pittsburgh, Pa.

Buffalo Section

The first regular meeting of the Buffalo Section of A.S.L.E. was held in the Ball Room of the General Brock Hotel, Niagara Falls, Canada, on October 17, 1946.

Dinner was served to seventy-seven members and guests.

Guest speakers for the evening were:

Dr. William Parché, Lubrication and Bearing Engineer, Carborundum Co., Niagara Falls, New York.

Mr. Walter D. Hodson, The Hodson Corp., Chicago, Illinois.

Dr. O. W. Ellis, Director of Research, Ontario Research Foundation, Toronto, Ontario.

Acting chairman, Walter Peuchen, made an introductory speech briefly outlining the future possibilities of the A. S. L. E. as a nationally known organization.

The first speaker was Mr. Hodson. The topic of Mr. Hodson's speech was "What is the A. S. L. E." He traced the history and growth of the organization and answered questions to "What is the A. S. L. E.," in the following eight facts:

1. "It is a society in which there is a place for any member, from the highest in position to everyone who has anything to do with the operation of the plant of an Industrial Organization. Every type of manufacturer or operating organization can be included, as well as railroads, steamship companies, airplane manufacturers—every type of public transportation."
2. "As provided by our by-laws, there is a place for the trainee, the Junior Lubrication Engineer, Lubrication Engineers, and companies themselves through our Industrial Membership Group."
3. "It represents an earnest group of men of the highest type of industry."
4. "In general, it is an exemplification of unselfishness. In what other similar undertaking have there been so many busy men of our largest and most important manufacturing companies who have spent so much time in building a society up from such a small beginning in such a short time, with its sections already extending—even though thinly—from the Atlantic to the Pacific Coasts, and even into foreign countries. The only Technical Society developing its efforts exclusively to lubricants and lubrication."
5. "A partnership between and of industrial men and the A.S.L.E."
6. "A combination of industrial operating personnel who, when coordinated into a harmonious cooperating group of any plant, will be the greatest influence for its successful operation — in all ways as a group—of the highest standards in plant operation as established by their education and training in chemistry, metallurgy, mechanical engineering and lubrication engineers."
7. "A unique technical development originating in industry within industry in response to industry's needs."
8. "An interdependent cooperating group of management and its engineering staff of lubrication men, chief engineers, mechanical engineers, master mechanics and maintenance superintendents, each independent in their technical societies or associations, to enhance their knowledge and skill for the mutual good of all, bound together with bonds of good will and common interest in their employer's company—management and engineers."

Dr. William Parché, Lubrication and Bearing Engineer, Carborundum Company, Niagara Falls, New York, gave a most interesting talk on the "Protection of Bearings in an Abrasive Atmosphere." In his speech he pointed out the need for analyzing the problem — "Where would the abrasion come from, and should we make an attempt to seal it from the bearing or to push enough lubricant through the bearing to carry away the abrasive material?"

Each case is a special problem and has to be treated as such. Dr. Parché gave several interesting case histories where, by proper protection of bearings the life of the equipment was extended many times.

Dr. O. W. Ellis, Director of Research, Ontario Research Foundation, Toronto, Ontario, Canada, gave most complete information on "How to Analyze Bearings and Classify Failures." He gave an excellent view of new bearing materials, the techniques used in fabricating these materials into bearings, and pointers on the proper design of bearings for maximum life with a minimum of maintenance.

The next speaker was Mr. George Miller who made a short talk on the A. S. L. E. and its relationship with industry.

It was moved and seconded and the Secretary was instructed to cast a unanimous ballot for the election of the following officers:

Walter Peuchen, Houde Engineering Company, Buffalo, New York—*Chairman.*

Mr. James Courtright, Shell Oil Co. of Canada, Toronto, Ontario—*Co-Chairman.*

Mr. James Farry, Alemite Co., Buffalo, New York—*Secretary-Treasurer.*

Dr. William Parché, Carborundum Co., Niagara Falls, New York, *Chairman of Program Committee.*

The next meeting will be held November 21, 1946, in Buffalo, New York at 6:30 p.m., at the Markeen Hotel.

Detroit Section

The Detroit Section held its first formal meeting Thursday, November 7th. This was in the form of an organization meeting and was attended by Dr. E. M. Kipp, President of the Society, who spoke about the Society and assisted the local group in their organization planning.

Mr. Jack Patt is in the throes of preparing the local By-Laws of the Section, and the Section itself is now under the able leadership of Mr. B. B. Phelps, Chairman, Mr. P. W. Uhl, Vice Chairman and Mr. R. W. Kenyon, Secretary-Treasurer.

The National Society welcomes its newest Section and looks forward to a very successful Section in the Detroit area.

Chicago Section

The Chicago Section opened its Fall season with a dinner meeting held September 27th in the Armed Forces Officers' Club. Following the dinner two interesting papers were presented, the first by Dr. Eugene Lieber of the Nox Rust Chemical Corporation on "The Lubrication Engineer's Guide to Modern Rust Preventives." The second paper was a discussion of "Silicones — New Engineering Materials" by Roger W. Kolderman of the Dow Corning Corporation. Both of these papers were extremely well received and followed by an active discussion which continued long after the formal part of the meeting had closed.

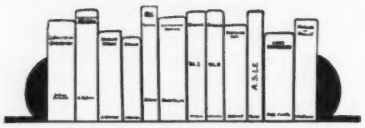
The second meeting of the year was held November 22nd at the Armed Forces Officers' Club. At this meeting Charles Bailey of the Inland Steel Company gave an interesting discussion on "The Organization of a Lubrication Department" and Charles K. Goldberg of the Chicago Mechanical Engineering Company spoke on the "Use of Lubricating Oils as Hydraulic

Media." The papers were very interesting and elicited an active discussion.

It was announced that the next program would cover the topic of "The Storage, Handling and Dispensing of Lubricants" with several speakers.

Mr. W. F. Leonard announced that the Industrial Membership Campaign of the Society, under the able leadership of Mr. W. D. Hodson, was now under way and invited the assistance of all the members of the Society. It is important, in the interest of Society progress, that Industrial or Company members join hand in hand with individual members in furthering the status of lubrication.

News has come to the Chicago Section that one of its members, Clarence Weidling of the Socony Vacuum Oil Company, because of ill health has decided to take a three months' leave of absence. All of the Section give him their best wishes and look forward to welcoming him back when he returns from his leave.



REVIEWS OF CURRENT BOOKS

SCIENTIFIC INSTRUMENTS

By H. J. Cooper (South-West Essex Technical College)

Chemical Publishing Company, Inc., Brooklyn, New York—1946. 305 pages, Price $6.00.

The aim of the book, as stated in the preface, is to "describe (instruments) in a way that may be understood by the non-specialist so that the worker in one field may get a useful idea of the instruments used in another. The book does not set out to tell the specialist about his own equipment but about the other man's."

The aim is probably well enough realized within the limits imposed by the size of the work and the selection of the devices described. The descriptions are non-technical and are illustrated either with simple and clear line drawings or with reproductions of photographs.

Approximately one third of the book is devoted to descriptions of lenses, cameras, microscopes, including the electron microscope, spectroscopes, photometers, polarimeters, etc. Other chapters treat devices for measurement of fluid densities, fluid quantities, fluid viscosity, pressure, time, weight, temperature, and electric current and power. A section of about forty pages covers navigational and surveying instruments.

It is difficult for this reviewer to understand the basis for the editor's selection of topics to be discussed. Why, for instance, should X-Ray and mass spectographs be included, p-H meters and thermal conductivity analysis cells be omitted, and space devoted to vernier calipers and calculating machines?

Even though there seem to be some important omissions, the book would nevertheless be a desirable addition to a library especially for the section on optical instruments.

I. T. WETZEL,
Northwestern University.

Plans for A.S.L.E. Convention in March

The Second Annual A.S.L.E. Convention will be held March 17, 18 and 19, 1947, with headquarters at the William Penn Hotel in Pittsburgh.

The Program, Planning and Publications Committee, headed by Mr. N. C. Penfold, is assembling an outstanding list of speakers and papers. An active local committee is preparing to show those attending the Convention real Pittsburgh hospitality and entertainment. On the local committee are G. H. Davis, E. M. Kipp, M. A. Stillwagon, H. E. Mahncke and G. L. Sumner.

Technical sessions are tentatively planned for Monday and Tuesday afternoons and Tuesday and Wednesday mornings, with a Smoker being arranged for Monday night and the Banquet Tuesday evening. Entertainment and a speaker of national importance will hold sway at the night meetings.

An inspection trip is also being planned for one of the afternoons.

Early in 1947 the preliminary program and registration cards for space at the hotel will be mailed. It is suggested that these be returned promptly as space at the hotel is at a premium although the Society has been guaranteed a reasonably large block of rooms for the Convention.

As in the past, no registration fee will be charged members for the Convention. However, non-members will pay a registration fee of $2.00. In the case of those who are eligible for membership in the Society, this registration fee can be credited on their first year's dues if application for membership is made within 30 days subsequent to the Convention.

An attendance for in excess of the 300 present at the Chicago meeting last year is being anticipated by the Committee.

A national sales conference of managers and field representatives of E. F. Houghton & Co. was held in Philadelphia October 7-9. More than 100 members of the sales organization traveled a total of nearly 100,000 miles from every section of the country to attend this conference, the first national meeting since before the war.

New products for peace-time industrial production were announced and graphically explained. These included new series of industrial rust preventives, metal cleaners, foundry core binders, wetting agents, detergents, textile finishes, synthetic packings, cutting oils, and heavy-duty lubricants.

Product sessions were held on October 7th and 8th, followed by a dinner tendered the visiting sales force by the company's Board of Directors, headed by Major A. E. Carpenter. Visitation of the company's Philadelphia plants was held on October 9th.

The committee handling the details of the meeting included G. W. Pressell, Executive Vice-President; D. J. Richards, Vice President—Sales; H. E. Sanson, Eastern General Sales Manager, and D. C. Miner, Advertising Manager.

Members of the American Society of Lubrication Engineers*

(As of November 15, 1946)

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General Motors Corp.
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Assoc. Prof. of Mach. Design
Cornell University
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Alemite Co. of So. Calif.
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6921 W. Rogers Street
West Allis 14, Wisconsin

*Company affiliations are given in italics—addresses indicated are preferred mailing addresses.

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Glenshaw, Pennsylvania

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American Oil Co.
1301 Grant Building
Pittsburgh, Pennsylvania

BOSWELL, THOMAS L.
Elgin National Watch Co.
Elgin National Watch Co.
107 National Street
Elgin, Illinois

BOURNE, JOHN P.
Standard Oil Co. (California)
3670 Fillmore Street
San Francisco 23, California

BOWDEN, WILLIAM
Firestone Tire & Rubber Co.
1945 11th Street
Cuyahoga Falls, Ohio

BOWEN, ALFRED F.
Socony Vacuum Oil Co.
1193 Virginia Avenue
Lakewood, Ohio

BOWERS, D E.
General Petroleum Corp.
General Petroleum Corp.
2721 E. 37th Street
Los Angeles, California

BOWERS, GEORGE F.
Standard Oil Co. (Ind.)
Standard Oil Co. (Ind.)
910 S. Michigan Avenue
Chicago 80, Illinois

BOWMAN, VIRGIL E.
Socony Vacuum Oil Co.
72 S. 6th Avenue
LaGrange, Illinois

BOWMAN, WILIAM K.
Union Oil Co. of Calif.
3450 Ben Lomond Place
Los Angeles 27, Calif.

BOYD, JOHN
Westinghouse Electric Corp.
Westinghouse Electric Corp.
Research Lab.—Ardmore Boulevard
East Pittsburgh, Pennsylvania

BRACE, R. LYLE
Brace Engineering Company
Brace Engineering Company
915 Valley St.
Dayton 4, Ohio

BRAND, EDGAR E.
L. Sonneborn Sons, Inc.
L. Sonneborn Sons, Inc.
400 West Madison Street
Chicago 28, Illinois

BRANDT, JOSEPH A.
Western Brass Mills-Olin, Inc.
Round Hill Road
Hamden 14, Connecticut

BRENHOLTZ, GEORGE W.
N. Y. and N. J. Lubricant Co.
N. Y. and N. J. Lubricant Co.
2328 Lamberton Road
Cleveland Heights 18, Ohio

BRENNAN, THOMAS L.
Gulf Oil Corp.
4 Crescent Place
Cranford, N. J.

BREWER, ALLEN F.
The Texas Co.
The Texas Co.
135 E. 42nd Street
New York, New York

BREZA, GEORGE
Mackintosh-Hemphill Co.
Mackintosh-Hemphill Co.
901 Bingham Street
Pittsburgh 3, Pennsylvania

BRIGHT, JOHN G.
Socony Vacuum Oil Co., Inc.
1209 South Negley Avenue
Pittsburgh 17, Pennsylvania

BRIZZOLARA, RALPH D.
American Steel Foundries
American Steel Foundries
410 North Michigan Avenue
Chicago 11, Illinois

BROOKS, W. M.
Allis Chalmers Supercharger
3077 S. 54th Street
Milwaukee 14, Wisconsin

BROSSEAU, LOUIS C.
Hodson Corporation
Hodson Corporation
5311 W. 66th Street
Chicago, Illinois

BROWN, ELTON S.
Standard Oil Co. (N. J.)
P. O. Box 32
Fairmont, W. Va.

BRYANT, M. W.
Shell Oil Company, Inc.
Shell Oil Company, Inc.
1133 S. Marengo Avenue
Pasadena, California

BRYANT, WILLIAM C.
Swan Finch Oil Corp.
5172 W. 63rd Place
Chicago 38, Ill.

BUDERUS, W. H.
Sinclair Refining Co.
3207 Royton Road
Toledo 9, Ohio

BULLARD, ROBINSON D.
Bullard Co.
P. O. Box 564
Southport, Connecticut

BURT, LOUIS B.
Lincoln Engineering Co.
8022 Drexel Avenue
Chicago 19, Illinois

CAIRNS, G. A.
Macco Products Co.
Macco Products Co.
525 West 76th Street
Chicago 20, Illinois

CALLAGHAN, ANDY
American Oil and Grease Co.
American Oil and Grease Co.
201 N. Wells Street
Chicago 6, Illinois

CALLAHAN, JOHN X. J.
299 E. South St.
Wilkes Barre, Pa.

CALVERLEY, H. R.
Shell Oil Co., Inc.
Shell Oil Co., Inc.
2201 W. 3rd Street
Cleveland, Ohio

CAMPBELL, MILTON H.
Standard Oil Co. (Ohio)
Standard Oil Co. (Ohio)
2127 Cornell Road
Cleveland 6, Ohio

CAMPBELL, W. E.
Bell Telephone Laboratories
Bell Telephone Laboratories
Murray Hill, N. J.

CARLIN, AUSTIN E.
Lake Shore Oil Co.
Lake Shore Oil Co.
5331 West 65th Street
Chicago, Illinois

CARLIN, WILLIAM
Pennzoil Co.
R. F. D. No. 2
Box 320
Jeannette, Pennsylvania

CARR, EDWIN B.
Socony-Vacuum Oil Co.
7653 East End Ave.
Chicago 49, Illinois

CARR, ROBERT W.
Alemite Company
11008 Nottingham Road
Detroit 24, Michigan

CARSON, RALPH W.
Alemite Company
No. 9 Beverly Drive
R. D. No. 1
Wescoesville, Pennsylvania

CARTER, LINDSAY P.
Production Supply Company
Production Supply Company
1927 Granville Street
Vancouver, British Columbia

CASSIDY, R. G.
Filmite Oil Corp.
Filmite Oil Corp.
Station K
Milwaukee 10, Wisconsin

CHADBURN, ALFRED
1008 Times Star Bldg.
Cincinnati 2, Ohio

CHALMER, STANLEY OSRIC
Commonwealth Oil Refineries, Ltd.
Commonwealth Oil Refineries, Ltd.
90 William Street
Melbourne, C1, Australia

CHAPIN, NOEL
Cites Service Oil Co.
Cites Service Oil Co.
927 1st National Bank Bldg.
Springfield, Ohio

CHAPPELL, PAUL F.
American Oil Co.
8 Mayflower Court
Pikesville 8, Maryland

CHAPPELLE, C. V.
Sinclair Refining Company
Box 64
Saukville, Wisconsin

CHRISMAN, ROBERT R.
American Oil Company
American Oil Company
Grant Building
Pittsburgh, Pennsylvania

CHRISTIAN, C. W.
General Petroleum Corp.
General Petroleum Corp.
108 West 2nd Street
Los Angeles 12, California

CLARK, WILLIAM F.
Weinman Pump & Supply Co.
Weinman Pump & Supply Co.
207-209 Blvd. Allies
Pittsburgh 22, Pennsylvania

CLINGEN, JOHN, JR.
Alemite Co. of Wis., Inc.
Alemite Co. of Wis., Inc.
1010 Van Buren Street
Milwaukee, Wisconsin

CLOWER, JAMES I.
University of Delaware
University of Delaware
Evans Hall
Newark, Delaware

COKINDA, ROBERT MILTON
Shell Oil Co., Inc.
105 Mill River Ave.
Lynbrook, L. I.
New York

COLE, RONALD H.
Alemite Co. of So. Calif.
Alemite Co. of So. Calif.
333 West Washington Blvd.
Los Angeles 15, California

COMNAS, GEORGE DEMETRIC
Standard Oil Co. of N. J.
Standard Oil Co. of N. J.
30 Rockefeller Plaza
New York 20, New York

CONNELL, KENNETH T.
Shell Oil Company, Inc.
120 25th Street
Hermosa Beach, California

CONOVER, HUGH B.
Carnegie Illinois Steel Corp.
Carnegie Illinois Steel Corp.
434 Fifth Avenue
Pittsburgh, Pennsylvania

CONTURBA. CHARLES E.
L. R. Kearns Co.
Box 901—R. R. No. 1
Waukesha, Wisconsin

COOK, CHARLES FAIRALL
Pullman Std. Car Mfg. Co.
1605 Euclid Avenue
Chicago Heights, Illinois

CORSON, BURTON F.
Shell Oil Company, Inc.
423 Rosebank Avenue
Baltimore 12, Maryland

COULTER, R. E.
Alemite Co. of Wis., Inc.
Alemite Co. of Wis., Inc.
1010 N. Van Buren Street
Milwaukee 2, Wisconsin

COURTRIGHT, JAMES M.
Shell Oil Co. of Canada, Ltd.
Shell Oil Co. of Canada, Ltd.
112 Yonge Street
P. O. Box 400
Toronto, Ontario

COWLEY, CLAUDE F.
Fiske Bros. Refining Co.
Fiske Bros. Refining Co.
6-225 Gen. Mtrs. Building
Detroit 2, Michigan

COX, WILLIAM, JR.
Elco Lubricant Corp.
Elco Lubricant Corp.
Jennings Road and Denison Ave.
Cleveland 9, Ohio

CRAINE, S. D.
Socony Vacuum Oil Co.
715 Hillside Avenue
Glen Ellyn, Illinois

CRANKSHAW, ALDEN
Acheson Colloids Corp.
Acheson Colloids Corp.
50 Church Street
New York 7, New York

CRANKSHAW, EDWIN
Cleveland Graphite Bronze Co.
Cleveland Graphite Bronze Co.
17000 St. Clair Street
Cleveland 10, Ohio

CRIPE, G. D.
Sinclair Refining Co.
P O. Box 106
North Jackson, Ohio

CUNNINGHAM, GEORGE A.
Imperial Oil Ltd.
Imperial Oil Ltd.
Welland, Ontario, Canada

CUTHBERT, WILLIAM LESLIE
Esso Standard Oil, S. A.
Esso Standard Oil, S. A.
22 Abercrombie Street
Port of Spain, Trinidad, B. W. I.

DANIEL, CHARLES E.
Shell Oil Co., Inc.
Shell Oil Co., Inc.
2015 Long Beach Ave.
Los Angeles, Calif.

DANSE, L. A.
General Motors Co.
General Motors Co.
15-223 Gen. Mtrs. Bldg.
Detroit 2, Michigan

DARDING, GEORGE A.
Wright Aeronautical Corp.
6944 Silverton Avenue
Silverton 13, Ohio

DAUBERT, G. A.
Nox-Rust Corp.
Nox-Rust Corp.
2429 South Halsted Street
Chicago 8, Illinois

DAVIS, GEORGE C.
Davis-Howland Oil Corp.
Davis-Howland Oil Corp.
South Avenue at Griffith
Rochester 7, New York

DAVIS, GEORGE H.
Shell Oil Co., Inc.
Shell Oil Co., Inc.
523 Grant Building
Pittsburgh 19, Pennsylvania

DEA, JOHN H.
Texas Company
Texas Company
5061 W. State Street
Milwaukee, Wisconsin

DE MARTONFALVY, IVAN CHARLES
Uni-Gun Lubrication Equipment Ltd.
36 Garden Close Ruislip
Middlesex, England

DENIGAN, EDWARD P.
Blow Knox Co.
Blow Knox Co.
829 Beaver Avenue
Pittsburgh 12, Pennsylvania

DEUTSCH, WILBUR
Brooks Equipment Co.
Brooks Equipment Co.
636 Potrero Avenue
San Francisco 10, California

DEVER, HUBERT J.
Alemite Co. of Eastern Pa.
Alemite Co. of Eastern Pa.
704 N. 16th Street
Philadelphia 30, Pennsylvania

DIX, RALPH GOODMAN
Cities Service Oil Co.
1136 Broad Avenue, N. W.
Canton 3, Ohio

DONALDSON, JOHN
Apex Alkali Prod. Co.
Apex Alkali Prod. Co.
Main & Rector Streets
Philadelphia 27, Pennsylvania

DONKER, A. E.
Honan-Crane Corp.
Honan-Crane Corp.
50 Church Street
New York, New York

DOUSSEAU, EDWIN L.
L. R. Kerns Co.
L. R. Kerns Co.
2657 E. 95th Street
Chicago 17, Illinois

DOYLE, PAUL J.
Republic Steel Corp.
Republic Steel Corp.
3100 E. 45th Street
Cleveland, Ohio

DRAKE, WILLIAM L.
Sinclair Refining Co.
2114 Woodstock Place
Milwaukee, Wisconsin

DRYER, JOHN P.
The Texas Company
33715 Duncan Street
Fraser, Michigan

DUNIGAN, JOHN HARMON
S. K. F.
S. K. F.
Front and Erie Streets
Philadelphia, Pennsylvania

DUNN, LEWIS C.
E. F. Houghton & Company
E. F. Houghton & Company
7 East Grand Avenue
Detroit 3, Michigan

DUNNE, GEORGE R.
Pure Oil Company
4022 N. Ashland Avenue
Chicago 13, Illinois

DuVAL, EUGENE HUDSON
Carbide & Carbon Chemical Co.
Carbide & Carbon Chemical Co.
4400 Fifth Avenue
Pittsburgh, Pennsylvania

DYE, GEORGE H.
Socony-Vacuum Oil Co.
Socony-Vacuum Oil Co.
1445 W. 37th St.
Chicago 9, Illinois

EBERLE, WILLIAM FREDERICK
The Neville Co.
The Neville Co.
Neville P. O.
Pittsburgh 25, Pennsylvania

EDER, NORMAN GEORGE
Kendall Refining Co.
Kendall Refining Co.
Bradford, Pennsylvania

EDGEHILL, JAMES GEOFFREY BRUCE
Esso Standard Oil Co. (Antilles) SA
Esso Standard Oil Co. (Antilles) SA
19 Water Street
Georgetown, British Guiana

EGGER, CHARLES J.
Buckeye Laboratories Corp.
25431 Hall Drive
Westlake, Ohio

EHRET, E. J.
Farval Corp.
Farval Corp.
327 South LaSalle Street
Chicago 4, Illinois

EHRLICH, MELVILLE
American Lubricants, Inc.
American Lubricants, Inc.
1575 Clinton Street
Buffalo 6, New York

EICHELBERGER, WILLARD C.
American Oil Co.
3054 Mayfield Ave.
Baltimore 13, Maryland

EISMANN, WILLIAM, JR.
E. F. Houghton & Co.
515 Stahr Road
Elkins Park 17, Pennsylvania

EKLUND, PHILLIP R.
Westinghouse Electric Corp.
408 Whitney Avenue
Pittsburgh 21, Pennsylvania

ELLIMAN, SAMUEL
Vigzol Oil Refining Co.
Vigzol Oil Refining Co.
113 Park Street
London, W 1, England

ELVIN, KENNETH WILLIAM
Sun Oil Company
134 Watchung Avenue
Montclair, New Jersey

ENNIS, H. E.
The Texas Co.
The Texas Co.
31 Terminal Way
Pittsburgh 19, Pennsylvania

EPPS, MAX
General Petroleum Corp.
General Petroleum Corp.
108 W. 2nd St.
Los Angeles 12, California

EVANS, ALLEN C.
The Texas Company
450 Homer Avenue
Akron 2, Ohio

EVANS, DOUGLAS N.
Inland Steel Co.
Inland Steel Co.
East Chicago, Indiana

EVANS, THOMAS J., JR.
Socony Vacuum Oil Co.
9831 S. Seeley Street
Chicago 43, Illinois

EVERETT, JAMES M., JR.
Balcrank Sales and Service Co.
Balcrank Sales and Service Co.
908 Sixth Ave., N.
Birmingham 1, Alabama

EVERITT, WILLIAM THEODORE
Eastman Kodak Co.
Eastman Kodak Co.
Kodak Park
Rochester, New York

EWBANK, WALTER JAMES
Briggs Filtration Co.
Briggs Filtration Co.
Bethesda 14, Maryland

EWING, FRANCIS ROBERT
Master Lubricants Company
315 New York Avenue
Brooklyn 13, New York

FAHEY, JOSEPH J.
Faber Laboratories of N. Y.
Faber Laboratories of N. Y.
51-57 Franklin Street
New York 13, New York

FAIRCHILD, SHERMAN M.
Fairchild Engine & Airplane Corp.
Fairchild Engine & Airplane Corp.
30 Rockefeller Plaza
New York 20, New York

FARRINGTON, BRUCE B.
California Research Corp.
California Research Corp.
P. O. Box 1627
Richmond, California

FARRY, JAMES E.
Alemite Co.
348 Florida Ave.
Buffalo, N. Y.

FAUVER, JOHN W.
J. N. Fauver Company
19323 Griggs Avenue
Detroit 21, Michigan

FEWSMITH, A. GRANT
Panther Oil & Grease Mfg. Co.
Panther Oil & Grease Mfg. Co.
840 N. Main St.
Forth Worth 1, Texas

FIELD, ALBERT D.
Bethlehem Sp. Pt. Ship
Bethlehem Sp. Pt. Ship
Sparrows Point, Maryland

FINDLAY, GEORGE
Republic Steel Corporation
Republic Steel Corporation
1175 South Park Avenue
Buffalo 20, New York

FINK, SAM M.
Alemite Co. of Pittsburgh
Alemite Co. of Pittsburgh
201 Shady Avenue
Pittsburgh 6, Pennsylvania

FINKELMAN, JOHN L.
The Warren Refining & Chemical Co.
The Warren Refining & Chemical Co.
308 Euclid Avenue
Cleveland 14, Ohio

FINNERAN, PAUL J.
Standard Oil Co. of Ohio
2203 Maple Ave.
Zanesville, Ohio

FISHER, C. W.
Gulf Refining Co.
Route No. 3
Medina, Ohio

FISHER, FRANK G.
Honan-Crane Corp.
Honan-Crane Corp.
1200 Indianapolis Ave.
Lebanon, Indiana

FITCH, L. W.
Dingle-Clark Co.
Dingle-Clark Co.
1248 Engineers Building
Cleveland 14, Ohio

FITZGERALD, CORNELIUS F.
Alemite Co. of Pittsburgh
85 Hilton Avenue
Youngstown 5, Ohio

FLETCHER, HARRY B.
Honan-Crane Corp.
Honan-Crane Corp.
501 West 7th Street
Plainfield, New Jersey

FOLLMER, CARL FRED
Thompson Aircraft Products Co.
R. F. D. No. 2, Box 150
Rome, Ohio

FOWLER, BURTON C.
Socony-Vacuum Oil Co.
Socony-Vacuum Oil Co.
130 Pearl Street
Buffalo 3, New York

FOX, ALEX P.
Lincoln Engineering Co.
Lincoln Engineering Co.
5701 Natural Bridge Avenue
St. Louis 20, Missouri

FRASER, HAROLD M.
International Lubricant Corp.
International Lubricant Corp.
P. O. Box 390
New Orleans 1, Louisiana

FREDERICKS, DONALD E.
L. R. Kerns Co.
6948 Paxton Ave.
Chicago, Illinois

FREDERICKS, W. CARLETON
Standard Oil Co. (Ind.)
Standard Oil Co. (Ind.)
910 South Michigan Avenue
Chicago 80, Illinois

FREEMAN, EDWIN W.
Cities Service Refining Corp.
Cities Service Refining Corp.
Hodges Street
Lake Charles, Louisiana

FREMON, E. B.
Socony Vacuum Oil Co., Inc.
Socony Vacuum Oil Co., Inc.
4140 Lindell Street
St. Louis 8, Missouri

FRIER, JAMES H.
Kaiser Company, Inc.
Iron & Steel Div.
2875 Wall Street
San Bernardino, California

FRIER, JAMES W.
Alemite Co. of So. Calif.
1730 Veranado Street
Altadena, California

FROHMAN, OSCAR
Ampco Metal, Inc.
4478 North Cramer Street
Milwaukee 11, Wisconsin

FULLER, DUDLEY D.
Columbia University
Department of Mechanical Engr.
Columbia University
New York 27, New York

GALINAS, WILLIAM EDWARD
Thompson Products, Inc.
14503 Orinoco Ave.
Cleveland 12, Ohio

GATES, PAUL J.
The F. D. Johnson Co.
The F. D. Johnson Co.
1814 East 40th Street
Cleveland 3, Ohio

GAUL, JOHN W.
Texas Co.
Texas Co.
Rand Bldg.
Buffalo 3, New York

GEEN, CORY P.
Sun Oil Co.
"Glencrest" R. D. No. 1
Chalfont, Bucks County
Pennsylvania

GENTHE, WALTER A.
The Texas Co.
The Texas Co.
332 South Michigan Avenue
Chicago 4, Illinois

GEORGI, CARL W.
Quaker State Oil Refining Corp.
Quaker State Oil Refining Corp.
164 Chandler Street
Buffalo 7, New York

GIEG, CHARLES F.
Shell Oil Co., Inc.
Shell Oil Co., Inc.
1725 E. Market Street
Akron, Ohio

GILL, FRANK P.
Adam Cook's Sons Inc.
Adam Cook's Sons Inc.
5 Stiles Street
Linden, New Jersey

GILLETTE, CHARLES R.
New Departure Div., Gen. Mtrs. Corp.
Vanderbilt Road
Bristol, Connecticut

GITZEN, JOSEPH A.
Delta Oil Products Co.
Delta Oil Products Co.
6263 North Teutonia Avenue
Milwaukee 9, Wisconsin

GJERDE, M. D.
Standard Oil Co. (Ind.)
Standard Oil Co. (Ind.)
910 South Michigan Avenue
Chicago 80, Illinois

GLENN, BRUCE W.
L. R. Kerns Co.
L. R. Kerns Co.
2657 East 95th Street
Chicago 17, Illinois

GOBLE, R. D.
Skinner Purifiers, Inc.
2331 North 8th Street
Milwaukee 6, Wisconsin

GODARD, P. W.
Sinclair Refining Co.
904 Peachtree Street, N. E.
Atlanta, Georgia

GODDARD, HOMER A.
Gulf Oil Corp.
Gulf Oil Corp.
Gross Street and P. R. R.
Pittsburgh 6, Pennsylvania

GODSHALL, J. BYRON
Ingersoll-Rand Co.
309 N. Tenth Street
Easton, Pennsylvania

GOLDSBOROUGH, F. C.
Sun Oil Co.
7327 Bryan St.
Philadelphia 19, Pennsylvania

GORDON, ROBERT M.
Gordon Lubricating Co.
Gordon Lubricating Co.
Gregg Street
Carnegie, Pennsylvania

GORSLINE, ROBERT J.
S. F. Bowser Co., Ltd.
40 37th Street
Long Branch, Ontario, Canada

GOTHARD, N. J.
Sinclair Refining Co.
Sinclair Refining Co.
East Chicago, Indiana

GOWER, CHARLES ARTHUR EDWARD
Socony Vacuum Oil Co., Inc.
Socony Vacuum Oil Co., Inc.
Federal Reserve Bank Building
Kansas City, Missouri

GRASSO, L. A.
The Texas Co.
The Texas Co.
31 Terminal Way
Pittsburgh 19, Pennsylvania

GRAVENSTRETER, JAMES P.
Carnegie Illinois Steel Corp.
Carnegie Illinois Steel Corp.
Gary Steel Works
Gary, Indiana

GRAVES, ELDON F.
Dow Chemical Co.
4014 Oak Court
Midland, C-8, Michigan

GRAY, L. J., JR.
J. G. Griffith Co.
J. G. Griffith Co.
1251 Union Trust Building
Pittsburgh 19, Pennsylvania

GRAY, L. L.
Gray Company, Inc.
Gray Company, Inc.
60 Eleventh Avenue, N. E.
Minneapolis, Minnesota

GREGG, JAMES KIRK
The Perfect Circle Co.
The Perfect Circle Co.
Hagerstown, Indiana

GREEN, ARTHUR W.
Ironsides Company
1745 East 71st Place
Chicago 49, Illinois

GRENIER, JOHN C.
Chevrolet Motor Co.
1605 Flushing Road
Flint 4, Michigan

GRIMMER, LANE E.
National Refining Co.
National Refining Co.
Glessnor Avenue
Findlay, Ohio

HAAS, H. A.
Blackmer Pump Co.
Blackmer Pump Co.
915 Union Trust Building
Pittsburgh 19, Pennsylvania

HAGAN, R. J.
Republic Steel Corp.
Republic Steel Corp.
Youngstown 1, Ohio

HAGER, H. R.
Sun Oil Co.
Sun Oil Co.
990 Home Avenue
Akron, Ohio

HAGGERTY, ALLAN J.
Haggerty Refining Co.
Haggerty Refining Co.
50 South St.
New York 5, New York

HALDEMAN, RUSSELL R.
De Laval Steam Turbine Co.
De Laval Steam Turbine Co.
853 Nottingham Way
Trenton 2, New Jersey

HALL, JAMES F.
Ironsides Co.
Ironsides Co.
270 West Mound Avenue
Columbus 15, Ohio

HAMMERSTEIN, FRED J.
Socony-Vacuum Oil Co.
7754 Saginaw Ave.
Chicago 49, Illinois

HARKINS, EDWIN D., SR.
Farval Corporation
Farval Corporation
2842 W. Grand Boulevard
Detroit, Michigan

HARPER, H. LEONARD
Aluminum Company of America
Aluminum Company of America
Gulf Building
Pittsburgh 19, Pennsylvania

HARRIS, SIDNEY GERALD
Petroleum Solvents Corp.
155 Chilton Street
Elizabeth, New Jersey

HART, ALAN
The Franklin Oil & Gas Co.
The Franklin Oil & Gas Co.
Bedford, Ohio

HASTINGS, S. A.
Crane Packing Company
Crane Packing Company
4418 N. Clark St.
Chicago 13, Illinois

HAUFE, TED B.
Universal Oil Products Co.
Universal Oil Products Co.
310 S. Michigan Avenue
Chicago 4, Illinois

HAZENFIELD, MILO CO.
Lincoln Engineering Co.
Lincoln Engineering Co.
134-136 S. Whitfield Street
Pittsburgh 6, Pennsylvania

HEATH, GEORGE F.
The Farval Corp.
The Farval Corp.
3249 East 80th Street
Cleveland 4, Ohio

HEILAND, JOHN GEORGE
Bell and Howell
1339 Center Ave.
Des Plaines, Illinois

HENKEL, HULL
Metal Lubricants Co.
Metal Lubricants Co.
3211 S. Wood Street
Chicago 8, Illinois

HERSEY, MAYO D.
Massachusetts Inst. of Tech.
Building 31
Massachusetts Inst. of Tech.
Cambridge 39, Massachusetts

HEWITT, FREDERICK M.
Bijur Lubricating Co.
Bijur Lubricating Co.
7-250 General Motors Bldg.
Detroit 2, Michigan

HEYER, ARTHUR J.
Sinclair Refining Co.
Sinclair Refining Co.
3030 Euclid Avenue
Cleveland, Ohio

HICKEL, ALBERT E.
Petroleum Research Abstracts
Petroleum Research Abstracts
30 W. Washington Street
Chicago 2, Illinois

HIDDEN, TODD C. E.
Alemite Co. of So. Calif.
319 23rd Place
Manhattan Beach, California

HIGGINS, EDWIN M.
Master Lubricants Co.
18 Hovey Street
Watertown, Mass.

HILLER, ED.
Essex Bross Corp.
Essex Bross Corp.
2000 Franklin Street
Detroit 7, Michigan

HISLOP, LAWRENCE D.
Standard Oil Co. of Pa.
455 Clokey Ave.
Pittsburgh 16, Pa.

HITZEMAN, MERLIN A.
Shell Oil Company, Inc.
Shell Oil Company, Inc.
2015 Long Beach Avenue
Los Angeles, California

HODSON, ELLIOTT W.
Hodson Corp.
Hodson Corp.
5301 W. 66th Street
Chicago 38, Illinois

HODSON, LEE N.
Hodson Corp.
Hodson Corp.
5301 W. 66th Street
Chicago 38, Illinois

HODSON, W. D.
Hodson Corp.
Hodson Corp.
5301 W. 66th Street
Chicago 38, Illinois

HODSON, WALTER H.
Hodson Corp.
Hodson Corp.
5301 W. 66th Street
Chicago 38, Illinois

HOFFMAN, GEORGE
Elco Lubricant Corp.
2635 East 128th Street
Cleveland 20, Ohio

HOFFMAN, STANLEY ROBERT
Standard Oil Co. (Indiana)
9136 S. Winchester Avenue
Chicago 20, Illinois

HOFMEISTER, HAROLD P.
Socony-Vacuum Oil Co.
2355 N. 82nd Street
Wauwatosa, Wisconsin

HOLLINGSWORTH, DWIGHT F.
E. I. duPont deNemours and Co.
E. I. duPont deNemours and Co.
1007 Market Street
Wilmington 98, Delaware

HOLMES, ROBERT L.
Ternstedt Mfg. Co.
1403 Liberty Avenue
Lincoln Park 25, Michigan

HOLT, JAMES OSCAR
Sinclair Refining Co.
3511 Neil Street
Raleigh, North Carolina

HOLTZ, HENRY G.
Taylor Forge and Pipe Works
7819 Clyde Ave.
Chicago 49, Illinois

HOWELL, K. M.
Standard Oil Co. (Ohio)
62 Pinehurst Avenue
Youngstown 5, Ohio

HUBBELL, H. W.
Kaiser-Frazer Corp.
32327 Kalamazoo Street
Wayne, Michigan

HULETT, W. E.
Socony Vacuum Oil Co.
1807 S. 10th Avenue
Maywood, Illinois

HUMES, ERWIN W.
Socony-Vacuum Oil Company
Socony-Vacuum Oil Company
903 W. Grand Boulevard
Detroit, Michigan

HUNTER, B. F.
Honan-Crane Corp.
403 E. Washington Street
Lebanon, Indiana

HURD, WILLIAM P., SR.
Socony Vacuum Oil Co.
10 Oakwood Avenue
Dayton 9, Ohio

HURTT, W. T.
United Oil Co.
United Oil Co.
1800 N. Franklin St.
Pittsburgh 12, Pa.

IRGENS, F. T.
Evinrude Motors
Evinrude Motors
4143 N. 27th Street
Milwaukee 9, Wisconsin

ISBELL, HARVEY G.
Industrial Laboratory
Industrial Laboratory
U. S. Navy Yard
Mare Island, California

JACOBSEN, PAUL W.
Honan-Crane Corp.
3499 S. 27th Street
Milwaukee, Wisconsin

JACOBSON, A. E.
H. K. Stahl Co.
H. K. Stahl Co.
2314 Wycliff St.
St. Paul 4, Minn.

JAESCHKE, ALFRED F.
National Refining Co.
National Refining Co.
122 South Michigan Avenue
Chicago, Illinois

JAMESON, HERBERT B.
Petroleum Equipment Co.
Petroleum Equipment Co.
3117 N. Broad Street
Philadelphia 32, Pennsylvania

JENKINS, WESLEY R.
Carnegie Illinois Steel Corp.
Carnegie Illinois Steel Corp.
3426 East 89th Street
Chicago, Illinois

JENNINGS, A. J.
The Farval Corp.
The Farval Corp.
3249 East 80th Street
Cleveland 4, Ohio

JENNINGS, BURGESS H.
Northwestern Technological Inst.
Northwestern Technological Inst.
Sheridan Road and Noyes Street
Evanston, Illinois

JESTER, MAXWELL B.
Calumet Refining Co.
Calumet Refining Co.
4323 South Western Boulevard
Chicago 9, Illinois

JESTER, S. VAN T., JR.
Shell Oil Company
Shell Oil Company
50 W. 50th Street
New York 20, New York

JOHNSON, ALBERT S.
Freedom-Valvoline Oil Co.
810 E. Lake Forest Avenue
Milwaukee 11, Wisconsin

JOHNSON, CHARLES B.
Pittsburgh Equitable Meter Co.
Pittsburgh Equitable Meter Co.
400 North Lexington Avenue
Pittsburgh 8, Pennsylvania

JOHNSON, CURTIS H.
Socony-Vacuum Oil Co.
1350 Boilvin Ave.
Rockford, Il.

JOHNSON, DARRYL W.
Standard Oil Co.
Standard Oil Co.
414 West Michigan Street
Milwaukee 1, Wisconsin

JOHNSON, FRANK D.
Trabon Engineering Corp.
Trabon Engineering Corp.
1814 East 40th Street
Cleveland, Ohio

JOHNSON, MARTIN A., JR.
Socony-Vacuum Oil Co.
Socony-Vacuum Oil Co.
59 E. Van Buren Street
Chicago, Illinois

JOHNSON, WILLIAM O.
Gulf Refining Co.
3370 Altamont Road
Cleveland Heights 18, Ohio

JOHNSTON, H. W.
Standard Oil Co.
1664 Lee Road
Cleveland Heights, Ohio

JOHNSTON, J. L.
Shell Oil Company, Inc.
Shell Oil Company, Inc.
P. O. Box 95
Wilmington, California

JONES, HAROLD H.
Harold H. Jones & Co., Ltd.
Harold H. Jones & Co., Ltd.
28 St. Georges Street
Capetown, South Africa

JONES, H. R., Jr.
Gulf Oil Corp.
202 Pennsylvania Blvd.
Pittsburgh 16, Pennsylvania

JONES, HAROLD WILLIAM
Penola, Inc.
3724 Rolliston Road
Cleveland, Ohio

JONES, WILLIAM
Gulf Oil Corp.
121 South Pasadena Drive
Aspinwall 15, Pennsylvania

JONES, WILLIAM CARTER
Carbide and Carbon Chemicals Co.
Carbide and Carbon Chemicals Co.
311 Ross St.
Pittsburgh 19, Pa.

JUDS, ARTHUR F.
A. F. Juds Oil Co.
A. F. Juds Oil Co.
531 South Water Street
Milwaukee 4, Wisconsin

JUSTICE, R. W.
E. F. Houghton and Co.
260 Pennsylvania Avenue
Youngstown 4, Ohio

KARTHAUSER, CARL A.
Self
207 Investment Building
Pittsburgh 22, Pennsylvania

KASMARK, J. W.
Lincoln Engr. Co.
596 E. 103rd St.
Cleveland, Ohio

KASE, EARL M.
Phillips Petroleum Co.
801 Washington Boulevard
Oak Park, Illinois

KATZ, WILLIAM B.
Van Straaten Chemical Co.
Van Straaten Chemical Co.
337 West Madison Street
Chicago 6, Illinois

KAY, LEWIS M.
Sinclair Refining Co.
332 Eighth Street
Atlanta, N. E., Georgia

KAYSER, HENRY W.
The Falk Corp.
2472 N. 66th Street
Wauwatosa 13, Wisconsin

KELLY, EDWARD S.
The Budd Company
The Budd Company
12141 Charlevoix Avenue
Detroit 14, Michigan

KEMMERER, HAROLD RICHARD
Shell Oil Co., Inc.
Shell Oil Co., Inc.
P. O. Box 2527
Houston 1, Texas

KENYON, RUSSELL W.
L. R. Kerns Co.
2010 Mayburn Street
Dearborn, Michigan

KIEFER, ALBERT S.
Sinclair Refining Co.
Sinclair Refining Co.
2540 W. Cermak Road
Chicago 8, Illinois

KIELY, THOMAS M.
Black Bear Co., Inc.
Black Bear Co., Inc.
44-45 23rd St.
Long Island City 1, N. Y.

KILIMANN, WILLIAM
C. M. St. P. & P. R. R.
1518 North 60th Street
Milwaukee, Wisconsin

KIMPEL, CLINTON B.
Carnegie Illinois Steel Corp.
Carnegie Illinois Steel Corp.
Duquesne, Pennsylvania

KING, GEORGE R.
Buffalo Tank Corporation
13 Pierce Avenue
Hamburg (Erie), New York

KING, HAROLD M.
Standard Oil Company (Ohio)
17 E. Sacramento Avenue
Dayton 9, Ohio

KINSEY, JOHN D.
The Farval Corp.
The Farval Corp.
327 South LaSalle Street
Chicago 4, Illinois

KIPP, E. M.
Aluminum Co. of America
Aluminum Co. of America
New Kensington, Pennsylvania

KIRKWOOD, ARCH B., JR.
American Lubricants, Inc.
East River Road
Grand Island
New York

KLASING, GEORGE V.
Alemite Co.
920 Cullom Street
Chicago 13, Illinois

KLUMB, ROY L.
Jos. Schlitz Brewing Co.
Jos. Schlitz Brewing Co.
235 W. Galena Street
Milwaukee 12, Wisconsin

KOCH, CLIFFORD
Canfield Oil Co.
Canfield Oil Co.
3216 East 55th Street
Cleveland 4, Ohio

KOHN, E. J.
Tenn. Coal, Iron and RR. Co.
Tenn. Coal, Iron and RR. Co.
P. O. Box 35—Ensley Station
Birmingham 8, Alabama

KOVARIK, FRANK
Gits Brothers Manufacturing Company
Gits Brothers Manufacturing Company
1846 S. Kilbourn Avenue
Chicago 23, Illinois

KRAEMER, HERMAN C.
Servel, Inc.
Servel, Inc.
Morton Avenue
Evansville 20, Indiana

KRAUS, CHARLES I.
Alemite Div.—Stewart-Warner Co.
Alemite Div.—Stewart-Warner Co.
1826 Diversey Parkway
Chicago, Illinois

KRAUS, ROBERT A.
Republic Steel Co.
Republic Steel Co.
116th and Burley Street
Chicago, Illinois

KRAUSE, RICHARD H.
Allis Chalmers Mfg. Co.
1121 West Scott Street
Milwaukee 4, Wisconsin

KRAUSE, WALLACE H.
Allis Chalmers Mfg. Co.
1944 S. 72nd St.
West Allis 14, Wisconsin

KRESTAN, JOHN H.
Battenfeld Grease & Oil Co.
Battenfeld Grease & Oil Co.
P. O. Box 144
North Tonawanda, New York

KRUMMELL, HARRY D.
Socony-Vacuum Oil Co., Inc.
Socony-Vacuum Oil Co., Inc.
59 E. Van Buren St.
Chicago, Illinois

KUEBLER, WILLIAM P.
Westinghouse Elec. Corp.
2334 Franklin Avenue
Secane, Pennsylvania

KUNTZE, ERNEST A.
Sinclair Refining Co.
1316 S. Van Buren Street
Green Bay, Wisconsin

KYROPOULOS, PETER
California Inst. of Tech.
California Inst. of Tech.
1201 E. California St.
Pasadena 4, California

KYROPOULOS, SPYRO
California Inst. of Tech.
California Inst. of Tech.
1201 E. California St.
Pasadena 4, California

LAKE, THORNTON
F. D. Johnson Co.
F. D. Johnson Co.
1814 East 40th Street
Cleveland, Ohio

LAMPMAN, EDWIN A.
Acheson Colloids Corp.
Acheson Colloids Corp.
200 Magee Bldg.
Pittsburgh, Pennsylvania

LAMPORT, BERT J.
United Eng. & Fdy. Co.
United Eng. & Fdy. Co.
1st National Bank Building
Pittsburgh, Pennsylvania

LANDIS, WARREN C.
Shell Oil Company
Ocean and Machachusetts Avenue
Massapeana, Long Island
New York

LANG, WALTER E.
Acheson Colloids Corp.
6523 Nottingham Street
St. Louis 9, Missouri

LANGLEY, JAMES MAX
Cities Service Oil Co.
Cities Service Oil Co.
70 Pine Street
New York 5, New York

LANGWORTHY M. L.
The Texas Co.
The Texas Co.
135 East 42nd Street
New York 17, New York

LARSEN, ROBERT G.
Shell Development Co.
Shell Development Co.
Emeryville 8, California

LARSON, C.M.
Sinclair Refining Co.
Sinclair Refining Co.
630 Fifth Avenue
New York 20, New York

LA TOUR, CLIFFORD B.
E. F. Houghton & Co.
9815 Yates Avenue
Chicago 17, Illinois

LAWRENCE, JOHN W.
Elco Lubricant Corp.
Elco Lubricant Corp.
Jennings and Dennison Streets
Cleveland 9, Ohio

LEMPERT, FRANK C.
Tide Water Assoc. Oil Co.
Tide Water Assoc. Oil Co.
1510 Arrott Building
401 Wood Street
Pittsburgh 22, Pennsylvania

LENZ, EDWARD J.
Swan-Finch Oil Co.
Swan-Finch Oil Co.
735 North Water Street
Milwaukee, Wisconsin

LEONARD, WILLIAM F.
4541 Sheridan Road
Chicago, Illinois

LEROY, B. L.
Republic Steel Corp.
1128—17th Street, N. W.
Canton 3, Ohio

LEVALLY, JOHN R.
Lincoln Engineering Co. of Illinois.
Lincoln Engineering Co. of Illinois.
2415 South Michigan Avenue
Chicago 16, Illinois

LEWIS, RAY D.
Texas Company
3417 Erie Avenue
Cincinnati 8, Ohio

LEWIS, WILLIAM E.
The Pure Oil Co.
The Pure Oil Co.
39th & Neville Sts.
Pittsburgh 16, Pa.

LEY, RALPH M.
Shell Oil Co., Inc.
3240 South Burrell Street
Milwaulkee 7, Wisconsin

LIBERTHSON, LEO
L. Sonneborn Sons, Inc.
L. Sonneborn Sons, Inc.
88 Lexington Avenue
New York 15, New York

LICHTY, D. E.
National Refining Co.
2304 A Holt Ave.
Milwaukee 7, Wisconsin

LIEBER, EUGENE
Nox-Rust Chemical Corp.
Nox-Rust Chemical Corp.
2429 South Halsted Street
Chicago 8, Illinois

LIEBERMAN, ARTHUR ARNOLD
Petroleum Marketing Co.
1480 Darlene Drive
Box 335
La Habra Heights, California

LILLMARS, C. ARVID
Petroleum Equipment Co.
Petroleum Equipment Co.
3117 North Broad Street
Philadelphia, Pennsylvania

LINDQUIST, WILLIAM R.
Warren Refining and Chemical Co.
Warren Refining and Chemical Co.
5151 Denison Avenue
Cleveland, Ohio

LINDWAY, JOSEPH M.
Shell Oil Company
10565 Vernon Avenue
Huntington Woods, Michigan

LINK, G. H.
Shell Oil Co., Inc.
325 Mohawk Drive
Dearborn, Michigan

LINVILL, ALBERT C.
Farval Corp.
6632 Van Buren Street
Hammond, Indiana

LIVELY, THEODORE S.
The Texas Co.
12004 West Cherry Street
Milwaukee, Wisconsin

LOCKER, P. H.
Standard Oil Company (N. J.)
117 Church Street
Woodbridge, New Jersey

LO PRETE, JAMES U.
Alemite Co.
3557 West Outer Drive
Detroit 21, Michigan

LUNZ, GILBERT M.
Lincoln Engineering Co.
3035 West Wisconsin Avenue
Milwaukee 8, Wisconsin

LYKINS, JOSEPH D.
Wheeling Steel Co.
Wheeling Steel Co.
Yorkville, Ohio

LYON, WILLIAM HENRY
American Steel & Wire Co.
American Steel & Wire Co.
80 Hamilton Ave.
Trenton, N. J.

MAAG, O. L.
Timken Roller Bearing Co.
Timken Roller Bearing Co.
Canton 6, Ohio

MacBETH, WILLIAM
Standard Oil Co. of Pa.
Standard Oil Co. of Pa.
35th and W. V. R. R.
Pittsburgh, Pa.

MAGILL, F. R.
Sales Representative
1022 Empire Building
Pittsburgh, Pennsylvania

MAHNCKE, HENRY E.
Westinghouse Electric Corp.
Westinghouse Research Lab.
East Pittsburgh, Pennsylvania

MANDY, W. H.
The Texas Co.
154 Spring Grove Road
Cresent Hills
Wilkinsburg, Pennsylvania

MANTEUFFEL, ALLAN A.
Pure Oil Research & Dev. Labs.
2122 Miner Street
Des Plaines, Illinois

MARIS, JOHN H.
L. R. Kerns Co.
L. R. Kerns Co.
5579 Pershing Ave.
St. Louis 12, Missouri

MARKLE, EDWARD L.
Shell Oil Co., Inc.
17 Pelham Drive
Buffalo 14, New York

MARLOW, CHARLES WILLIAM
Standard Oil Co.
827 Magic Avenue
Elizabeth 3, New Jersey

MARTIN, RALPH V.
American Oil Company
R. F. D. No. 2
Bedford, Virginia

MARSHALL, W. A.
Alemite Co.
Alemite Co.
15501 Woodrow Wilson Avenue
Detroit 3, Michigan

MATTE, GERALD A.
Cities Service Oil Company (Pa.)
Cities Service Oil Company (Pa.)
70 Pine Street
New York 5, New York

MATTHEWS, RALPH R
Battenfeld Grease & Oil Co.
Battenfeld Grease & Oil Co.
3148 Roanoke Road
Kansas City 8, Missouri

MAY, EDWIN M.
Bowser, Inc.
Bowser, Inc.
420 Lexington Avenue
New York 17, New York

MAZZARA, ERNEST E.
Cities Service Oil Co.
71 Madison Avenue
West Hempstead, New York

McCARTHY, G. NORMAN
Texas Company
Texas Company
26 Lansing Street
Buffalo, New York

McCASLIN, R. H.
National Refining Co.
200 Eagle Point Road
Rossford, Ohio

McCLUNG, ERNEST E.
Van Straaten Chemical Co.
Van Straaten Chemical Co.
337 West Madison Street
Chicago 6, Illinois

McCURDIE, N. J.
Panelyte Div. St. Regis Paper Co.
Panelyte Div. St. Regis Paper Co.
230 N. Michigan Avenue
Chicago 1, Illinois

McCUTCHEON, CURTIS A.
Sinclair Refining Co.
45-42 43rd St.
Long Island City
New York

McGAR, BENJAMIN H.
Chase Brass & Copper Co., Inc.
Chase Brass & Copper Co., Inc.
236 Grand Street
Waterbury 91, Connecticut

McGINTY, ALFRED L. JR.
International Distributing Co.
International Distributing Co.
P. O. Box 2508
Birmingham 1, Alabama

McGROGAN, JOHN F.
Atlantic Refining Co.
4519 Princeton Avenue
Philadelphia 35, Pennsylvania

McHENRY, H. J.
Johns Manville
Johns Manville
610 Clarke Building
Pittsburgh 22, Pennsylvania

McKAIG, WILLARD H.
International Business Machines Corp.
International Business Machines Corp.
Endicott, New York

McKEE, JOHN R.
Fiske Bros. Refining Co.
13817 North Drive
Cleveland 5, Ohio

McKIBBEN, ROBERT F.
National Cash Register Co.
241 North Smithville Street
Dayton 3, Ohio

McLAUGHLIN, ED F.
Seaport Oil Co.
6123 Lebanon Ave.
Philadelphia 31, Pa.

McMURTRY, ERMIL W.
Sinclair Refining Company
318 N. Mount Street
Indianapolis, Indiana

McNARY, S. S.
Texas Company
Texas Company
31 Terminal Way
Pittsburgh 19, Pennsylvania

McPHEE, JOHN R.
Ironsides Company
P. O. Box 1409
Poland, Ohio

MEEK, PAUL F.
Standard Oil Co. (Ohio)
Standard Oil Co. (Ohio)
3272 West 115th Street
Cleveland 11, Ohio

MEIER, E. D.
Harvey Machine
139 Bay Shore Avenue
Long Beach 3, California

MERCER, MARC E.
Trabon Engineering Corp.
Trabon Engineering Corp.
225 E. Michigan St.
Milwaukee, Wisconsin

MERCHANT, MYLON EUGENE
Cincinnati Milling Machine Co.
Cincinnati Milling Machine Co.
Cincinnat 9, Ohio

MERGET, ANDREW E.
DeLaval Separator Company
DeLaval Separator Company
Pine & Water Street
Poughkeepsie, New York

MEYER, ARTHUR E.
Meyer Sheet Metal Machine Co.
Meyer Sheet Metal Machine Co.
1928 Santa Fe Avenue
Los Angeles 21, California

MILLER, ARTHUR A.
E. F. Houghton & Co.
E. F. Houghton & Co.
32 West Randolph Street
Chicago 1, Illinois

MILLER, GEORGE W.
Battenfeld Grease & Oil Corp.
Battenfeld Grease & Oil Corp.
Box 144
North Tonawanda, New York

MILLER, HARRY L.
Haas-Miller Corp.
Haas-Miller Corp.
4th and Bristol Streets
Philadelphia 40, Pennsylvania

MOHR, EDWARD A.
Shell Oil Company, Inc.
Shell Oil Company, Inc.
2015 Long Beach Avenue
Los Angeles, California

MONINGER, JAMES A.
Standard Oil Co. (Indiana)
Standard Oil Co. (Indiana)
715 East 10th Street
Wichita 1, Kansas

MONTALVO, EDWIN JAMES
James T. Gordon Co.
James T. Gordon Co.
233 Broadway
New York, New York

MONTZHEIMER, ARTHUR M.
Aluminum Company of America
Aluminum Company of America
Freeport Road
New Kensington, Pa.

MOOK, ARTHUR D.
Aluminum Company of America
Aluminum Company of America
Lafayette, Indiana

MORENS, RALPH MICHAEL
Lincoln Engineering Co.
2388 Stair Street
Detroit, Michigan

MORETON, DOUGLAS H.
Douglas Aircraft Company
Douglas Aircraft Company
3000 Ocean Park Boulevard
Santa Monica, California

MORGAN, EUGENE B.
Morgan Oil Co.
Morgan Oil Co.
Wvaconda, Missouri

MORTON, H. M.
Garlock Packing Company
Tippecanoe Road, R. D. No. 2
Canfield, Ohio

MOULD, ARTHUR E.
Tide Water Associated Oil Co.
22 Highland Drive
Williamsville, New York

MOUNTCASTLE, HENRY RICHARD
Swan-Finch Oil Corp.
P. O. Bor 6327
Pittsburgh 2, Pennsylvania

MUELLER, CARL H.
Lincoln Engineering Corp.
8645 Natural Bridge Ave.
St. Louis 21, Mo.

MUELLER, JULIUS T.
Falk Corporation
Box 175
Hustisford, Wisconsin

MULLER, HENRY
Shell Oil Co., Inc.
318 W. 106th Street
New York 25, New York

MURPHY, HARRY A.
Gray Co., Inc.
Gray Co., Inc.
60 - 11 Street N. E.
Minneapolis 13, Minnesota

MURPHY, JOHN J.
Twin Coach Company
210-D Gibson Street
Tonawanda, New York

MURPHY, WILLIAM P.
Lubri-Zol Corp.
12232 S. 71st St.
Palos Heights, Ill.

MURRAY, J. P.
Dingle-Clark Co.
Dingle-Clark Co.
311 Ross Street
Pittsburgh, Pennsylvania

NAGEL, JOHN Q.
Essex Brass Corp.
Essex Brass Corp.
2000 Franklin Street
Detroit 7, Michigan

NAGEL, PAUL L.
Essex Brass Corp.
Essex Brass Corp.
2000 Franklin Street
Detroit 7, Michigan

NEEDHAM, GEORGE P.
Sun Oil Company
998 Englewood Avenue
Cleveland Heights, Ohio

NEVILLE, GEORGE M.
Atlantic Refining Co.
54 Boardman Terrace
Wethersfield, Conn.

NEWMAN, ALEXANDER I.
Precision Scientific Co.
Precision Scientific Co.
1750 North Springfield Avenue
Chicago 47, Illinois

NEWMAN, THOMAS HART ODELL
Standard Oil Co. (N.J.)
30 Rockefeller Plaza
New York 20, N. Y.

NICHOLSON, ROSCOE F.
Honan-Crane Corp.
3306 Hamilton Ave.
Baltimore 14, Maryland

NIEDERLOH, EARL L.
Gray Co., Inc.
Gray Co., Inc.
60 - 11th Avenue, N. E.
Minneapolis 13, Minnesota

NINNEMANN, JOHN W.
Solventol Chem. Prod.
3437A—N. 46th Street
Milwaulkee 10, Wisconsin

NORDIN, JOHN G.
So. Calif. Gas Co.
So. Calif. Gas Co.
553 Ramirez Street
Los Angeles, California

NORGREN, CARL A.
C. A. Norgren Co.
C. A. Norgren Co.
222 Santa Fe Drive
Denver, Colorado

NORRIS, HENRY LEE
(Retired)
600 West 116th Street
New York 27, New York

NORRIS, WALTER
C. A. Norgren Co.
C. A. Norgren Co.
1251 West Fulton Street
Chicago 7, Illinois

O'FARRELL, ROBERT MAURICE
Esso Std. Oil (Caribbean) S. A.
Esso Std. Oil (Caribbean) S. A.
P. O. Box 1198
Ciudad Trujille, Dominican Republic

OLARTE, C. GARCIA
Tropical Oil Company
Tropical Oil Company
Bogota, Colombia
South America

OLIVER, GEORGE W.
Texas Co.
1931 Haverhill Drive
Dayton, Ohio

OLSEN, GODTFRED A.
Sunland Refining Corp.
Sunland Refining Corp.
P. O. Box 1512
Fresno 16, California

OLSEN, PAUL P.
General Petroleum Corp.
4516 W. Seattle Street
Seattle 6, Washington

ORMSBY, GEORGE W.
Standard Oil Co. (Ind.)
512 Lakeview
Port Huron, Michigan

O'SULLIVAN, EUGENE P.
The Texas Co.
The Texas Co.
332 South Michigan Avenue
Chicago 4, Illinois

PAAPE, LAWRENCE F.
Filmite Oil Corp.
2533 N. 97th Street
Wauwatosa 13, Wisconsin

PACHAL, ADOLPH
Service Station Equipment
81 Humberview Road
Toronto, Ontario

PALMER, CHARLES
Morgan Construction Co.
Morgan Construction Co.
15 Belmont Street
Worcester 5, Massachusetts

PARCHE, WILLIAM HENRY
Carborundum Company
Carborundum Company
P. O. Box 337
Niagara Falls, New York

PARR, ALLEN R.
Oldsmobile Div.—Gen Mtrs Co.
808 McKinley Street
Janesville, Wisconsin

PASHEK, ALBERT L.
Socony Vacuum Oil Co., Inc.
1473 Alameda Avenue
Lakewood 7, Ohio

PATE, A. M. JR.
Panther Oil & Grease Mfg. Co.
Panther Oil & Grease Mfg. Co.
P. O. Box 711
Fort Worth 1, Texas

PEEBLES, JAMES CLINTON
Illinois Institute of Tech.
Illinois Institute of Tech.
3300 South Federal Street
Chicago 16, Illinois

PELLETIER, PAUL E., JR.
L. R. Kerns Co.
L. R. Kerns Co.
2657 E. 95th Street
Chicago 17, Illinois

PENFOLD, NORMAN C.
Armour Research Foundation
Armour Research Foundation
35 West 33rd Street
Chicago 16, Illinois

PENNEY, WILLIAM F.
2052 Revely
Lakewood 7, Ohio

PENNOCK, WILLIAM T.
Alemite Sales Co., Inc.
559 Surf Street
Chicago 14, Illinois

PERRIGUEY, WILBUR G.
Standard Oil Co. (New Jersey)
39-07 210th Street
Bayside
Long Island, New York

PERKINS, H. P.
Texas Company
1320 W. North Street
Bethlehem, Pennsylvania

PETERSON, CARL G.
Falk Corp.
2523 West Pierce Street
Milwaukee, Wisconsin

PETERSON, R. E.
Westinghouse Electric Corp.
Westinghouse Electric Corp.
East Pittsburgh, Pennsylvania

PETERSON, J. WILLARD
Standard Oil Co. (Ind.)
Standard Oil Co. (Ind.)
910 South Michigan Avenue
Chicago, Illinois

PEUCHEN, WALTER G.
Houde Engineering Division
400 Goundry Street
N. Tonawanda, New York

PFAFF, EDWIN I.
Trabon Engineering Corp.
Trabon Engineering Corp.
1814 East 40th Street
Cleveland 3, Ohio

PHELPS, BENJAMIN B.
Detroit Transmission Div., GMC.
2156 Cadillac Blvd.
Detroit 4, Michigan

PHILLIPS, KENNETH
Self
5153 Hillcrest Street
Pittsburgh 24, Pennsylvania

PIERCE, W. C.
General Petroleum Corp.
General Petroleum Corp.
585 W. 5th Street, West
Salt Lake City, Utah

PIRKLE, MORGAN W.
Faber Laboratories of New York
Faber Laboratories of New York
51-57 Franklin Street
New York 13, New York

POMBO, O. GOMEZ
Tropical Oil Company
Tropical Oil Company
Barranquilla, Colombia
South America

POPSON, S. F.
Gulf Refining Co.
Gulf Refining Co.
1901 South 7th Street
Louisville 1, Kentucky

POTTER, RAYMOND I.
Standard Oil Co. (Ohio)
Standard Oil Co. (Ohio)
1784 Midland Building
Cleveland, Ohio

POULSON, H. R.
Johns-Manville
Johns-Manville
22 East 40th Street
New York, New York

POWERS, S. L.
Honan-Crane Corp.
Honan-Crane Corp.
606 Williamson Bldg.
Cleveland, Ohio

PRENDERGAST, WILLIAM A.
The Texas Co.
The Texas Co.
P. O. Box 509
Beacon, N. Y.

PRICE, DON C.
Bowser, Inc.
Bowser, Inc.
12652 Livernois Avenue
Detroit 4, Michigan

PRITCHARD, CHARLES E.
Republic Steel Corp.
Republic Steel Corp.
25 Prospect Street
Cleveland 1, Ohio

RADOSEVICH, GEORGE E.
Harnischfeger Corp.
1622 South 13th Street
Milwaukee 4, Wisconsin

RAFFEL, FRANK H.
Republic Steel Corp.
3105 Stimson Court
Cleveland 9, Ohio

RAISIG, CHARLES
Mesta Machine Co.
Mesta Machine Co.
Homestead
Pittsburgh, Pennsylvania

RANDALL, CLARK C.
Sinclair Refining Co.
Sinclair Refining Co.
2540 W. Cermak Road
Chicago 8, Illinois

RANDALL, MERLE
Randall and Sons
Randall and Sons
2512 Etna Street
Berkeley 4, California

RECTOR, GEORGE L.
Socony Vacuum Oil Co., Inc.
60 Academy St.
Pittsburgh 16, Pennsylvania

REAGAN, J. E.
Elco Lubricant Corp.
Elco Lubricant Corp.
Jennings Rd. & Dennison Ave.
Cleveland 9, Ohio

REGAN, ROBERT W.
Chrysler Corp.-Dodge Chi. Plant
1821 S. 50th Ct.
Cicero, Illinois

REISSIG, A. RICHARD
Socony-Vacuum Oil Co., Inc.
Hotchkiss Grove Road
Branford, Conn.

REILLY, C. TYSON
Standard Oil Company (Pa.)
1962 Howard Avenue
Pottsville, Pennsylvania

RENNO, ARTHUR A.
The Texas Company
Montgomery Court Apartments
Narberth, Pennsylvania

REPENNING, ROBERT F.
Shell Oil Co., Inc.
918 Crain Street
Evanston, Illinois

RETTIG, MARION H.
Bowser, Inc.
Bowser, Inc.
E. Creighton Avenue
Ft. Wayne 5, Indiana

REYNOLDS, E. S.
Socony Vacuum Oil Co., Inc.
118 Cochran Road
Pittsburgh 16, Pennsylvania

RICHARDS, DONALD L.
Carlisle Chemical Works
Carlisle Chemical Works
510 Reading Road
Reading 15, Ohio

RICHARDS, GEORGE W. II
Apex Alkali Prod. Co.
Apex Alkali Prod. Co.
Main and Rector Streets
Philadelphia 27, Pennsylvania

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Apex Alkali Prod. Co.
Apex Alkali Prod. Co.
Main and Rector Streets
Philadelphia 27, Pennsylvania

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The Warren Refining and Chemical Co.
The Warren Refining and Chemical Co.
5151 Denison Avenue
Cleveland 2, Ohio

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Trabon Engineering Corp.
Trabon Engineering Corp.
1022 Empire Building
Pittsburgh 22, Pennsylvania

ROBERSON, WILLIAM A.
G. & W. H. Corson, Inc.
149 Erdenheim Road
Chestnut Hill
Philadelphia 18, Penn.

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Gulf Oil Corp.
R. F. D. 1
Library, Pennsylvania

ROBISON, ROBERT V.
Dingle-Clark Co.
Dingle-Clark Co.
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Pittsburgh, Pennsylvania

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F. D. Johnson Co.
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Negley Hotel
Florence, Alabama

ROEHNER, T. G.
Socony-Vacuum Oil Co.
43 Locust Lane
Mt. Vernon, New York

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The Texas Co.
The Texas Co.
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New York 17, New York

ROSNELL, JOHN E.
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The Texas Company
332 South Michigan Avenue
Chicago 4, Illinois

ROSS, EDGAR S.
Sun Oil Co.
Sun Oil Co.
1608 Walnut Street
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E. F. Houghton and Co.
E. F. Houghton and Co.
4500 Euclid Avenue
Cleveland 3, Ohio

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Bellevue
Pittsburgh 2, Penn.

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Marquette Petroleum Products
7270 South Chicago Avenue
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Griffin Chemical Co.
1000-16th Street
San Francisco 7, California

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The J. W. Kelley Co.
13209 Athens Avenue
Cleveland 7, Ohio

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Sta-Vis Oil Co.
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548 Liberty Street
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17000 St. Clair Avenue
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The National Refining Co.
Hanna Building
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Allis-Chalmers Mfg. Co.
3614 W. Rogers Street
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244 The Boulevard
Pittsburgh 10, Pennsylvania

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Aluminum Research Labs.
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Black Bear Company, Inc.
44-45 23rd Street
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E. F. Houghton and Co.
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Alemite Co. of Wis., Inc.
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Milwaukee 2, Wisconsin

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Detroit 15, Michigan

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Socony Vacuum Oil Co.
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Milwaukee, Wisconsin

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Wolf's Head Oil Ref. Co.
Fair Building
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Mt. Lebanon 16, Penn.

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Sun Oil Co.
3200 Independence Road
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Panther Oil & Grease Mfg. Co.
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Fort Worth 1, Texas

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Socony Vacuum Oil Co.
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Steel Products Engineering
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McKeesport, Pennsylvania

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Circo Products Co.
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258 Mar Vista
Pasadena 4, California

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Standard Oil Co. of California
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Caltex House
Bombay, India

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Syracuse 10, New York

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102 W. 4th Street
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Detroit Diesel Engine Div.
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Detroit 13, Michigan

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79 Grant Avenue
Pittsburgh 2, Pennsylvania

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Cleveland, Ohio

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Tropical Oil Company
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Colombia, South America

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F & W Ursem Company
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Texas Company
Texas Company
135 East 42nd Street
New York 17, New York

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Cities Service Oil Co.
360 Addison Road
Riverside, Illinois

VILLING, JOHN A.
Valvoline Oil Company
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Butler, Pennsylvania

VON FUCHS, GEORGE H.
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Shell Oil Company, Inc.
Wood River, Illinois

VOSHELL, B. C.
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Socony-Vacuum Oil Co., Inc.
26 Broadway Avenue
New York 4, New York

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8719 Escanaba Avenue
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Henry H. Cross Co.
Henry H. Cross Co.
122 South Michigan Avenue
Chicago 3, Illinois

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Hoover Ball & Bearing Co.
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Chicago 17, Illinois

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Carnegie-Illinois Steel Corp.
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Slayton Settlement Road
Niagra County, New York

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A. O. Smith Corp.
3608 North 27th Street
Milwaukee 10, Wisconsin
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275 West Federal Street
Youngstown, Ohio
Mr. Wm. Rodder

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Mr. T. W. Allison

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Tidewater Oil Co. of Canada, Ltd.
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General Petroleum Corp.
108 West 2nd Street
Los Angeles 12, California

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Milwaukee 4, Wisconsin

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Sandard Oil Co. (Ind.)
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Chicago 80, Illinois

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Grafo Colloids Corp.
431 South Dearborn Street
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Humble Oil & Refining Co.
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Warren Refining and Chemical Co.
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557 South Braddock Avenue
Pittsburgh 21, Pennsylvania

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Carnegie Illinois Steel Corp.
Carnegie Building
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Cities Service Oil Co.
3200 South Western Avenue
Chicago 8, Illinois

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Alox Corporation
Alox Corporation
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Socony Vacuum Oil Co., Inc.
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Shell Oil Company, Inc.
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Omar Bakery, Inc.
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Shell Oil Co., Inc.
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New York, N. Y.

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Continental Steel Corp.
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Kokomo, Indiana

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Winslow Engineering Company
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Cities Service Oil Co.
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Freedom Oil Co.
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American Cyamid Co.
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Nordberg Mfg. Co.
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Warren Refining and Chemical Co.
308 Euclid Avenue
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Union Oil Co.
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Los Angeles 14, California

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Bijur Lubricating Corp.
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Cleveland Heights 21, Ohio

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Beacon, New York

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SUBJECT AND AUTHOR INDEX

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